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FURTHER OBSERVATIONS ON THE DISTRIBUTION OF STRIPED TUNA, *KATSUWONUS PELAMIS* L., IN EASTERN AUSTRALIAN WATERS, AND ITS RELATION TO SURFACE TEMPERATURE

By J. P. Robins*

(*Manuscript received November* 29, 1951)

Summary

The distribution of striped tuna in eastern Australian waters, as indicated by numbers of fish caught per line trolled, was investigated between August 1950 and August 1951. The temperature of the water was recorded every half hour while the vessel was cruising. The data obtained show that the distribution extended from at least as far north as Port Macquarie, New South Wales, to 40 miles south of Tasman Island, Tasmania — much further south than observed in previous years. Occurrence in abundance was seasonal in any specific area off the coast. Movement to the south from the mid north coast of New South Wales began in late spring; movement north from the east Tasmanian coast began in mid autumn.

Striped tuna were taken in eastern Australian waters of temperature ranging between 14.7 and 20.8°C., but occurred most plentifully between temperatures of 16.0 and 18.0°C. They had a preference for water of specific temperatures in the areas in which they occur seasonally. Seasonal movement north and south showed a strong correlation with seasonal changes in water temperatures. Commencement of movement northwards from the south appeared to be influenced by downward change in temperature, which brought about the lower limit of the critical temperature tolerated; this change was coincident with the onset of the seasonal westerly winds. Degree of southerly penetration is related to temperature, whose seasonal fluctuation could explain 'abnormal' years.

I. Introduction

Tuna investigations, begun in 1950, were at first concerned with the two species of tuna most commonly fished off the Australian east coast, the southern bluefin tuna (*Thunnus maccoyii* Castlenau 1872) and the striped tuna (*Katsuwonus pelamis* L.). The abundance of the two species and the environmental conditions in the areas in which they occur were studied.

The southern bluefin tuna is subject to marked annual fluctuations in abundance in this region (Thompson 1943; Serventy 1947 and unpublished data) and the possibility that it might not support an independent fishery has been suggested. Early in the investigation therefore effort was concentrated on striped tuna.

Striped tuna is widely fished by the live-bait and pole method off the Philippine Islands, Japan, Hawaii, and the Pacific coast of tropical and subtropical America. This method has also been demonstrated successfully in Australian waters (Flett 1944).

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'Abundance' is used in this paper to indicate the portion of the stock(s) frequenting the coast, i.e. availability for coastal fishing.

II. Outline of Investigations

The main body of data discussed in this paper was collected during cruises of Fisheries Research Vessel *"Stanley Fowler"* between late August 1950 and late August 1951.

The investigations were mainly concerned with (*a*) the collection of additional data on distribution as disclosed by numbers of fish caught per line trolled, and (*b*) the observation of serial surface temperatures.

(*a*) The search for tuna in 1950-51 was planned in accordance with their known occurrences and covered spring and early summer off the southern part of the New South Wales coast, late summer and autumn in Tasmanian east coast waters, and the winter and early spring off the central and northern parts of the New South Wales coast. Striped tuna were taken by trolling, by which method only fish in the upper water layers are caught.

(*b*) Temperature investigation of the coastal waters was attempted in three ways: meridionally, latitudinally, and bathymetrically. The first two methods gave information upon which the accompanying diagrams are based (Figs. 1-4; Fig. 4 is also partly based on data from hydrological files of this Division), but much further investigation with the third method in conjunction with a special fishing method (long-lining) is needed before any definite conclusions may be reached.

Temperature was recorded every half hour whilst the vessel was cruising, and the time of each catch and 'strike' (a hooked fish that is not brought aboard) was also recorded.

III. Distribution of Striped Tuna

(*a*) *Previous Data*

Serventy (1941 and unpublished data) stated that some fish are to be found in New South Wales waters throughout the year, but that they first appear in strength in October when shoals may be found from the Sydney area south to Jervis Bay and Brush Island. By November they have penetrated into Bass Strait and in December are off Flinders Island. In the late summer and early autumn they are further south. The southern limit of occurrence in *normal* seasons is the St. Helens to St. Patrick's Head region (Tasmania), beyond which the shoals disappear with extraordinary suddenness. In some years, however, they may venture further south, as in the abnormal year of 1942, when on March 28 the *"Warreen"* trolled striped tuna at Cape Pillar. Reference to striped tuna occurrence in summer and autumn from Bermagui, southern New South Wales, to St. Helens, Tasmania, was also made by Thompson (1943).

Little was known of the distribution from about June, when the last stragglers are observed in the Bass Strait to Tasmanian region, to about

October. A few fish had been taken and shoals seen at various places along the New South Wales coast and the southern part of the coast of Queensland (Serventy, unpublished data).

(*b*) *New Data*

During the 1950-51 season, extended investigations showed the fish to be distributed further to the south than the St. Helens area, a few fish being caught 140 miles to the south, while many were taken in the Tasman Island area.

In the months of June, July, and August 1951 the area from Bateman's Bay (lat. 35° 45′ S.) to Moreton Bay (lat. 27° S.) was investigated and trolling results showed that striped tuna occurred in quantity from Ulladulla to Port Stephens. None was taken further north and few were taken further south, but there had been a northward shift of abundance from southern New South Wales since May. In mid September 1951 (after the *"Stanley Fowler"* survey) striped tuna occurred in large numbers off Forster and Port Macquarie, which areas are 40 and 80 miles north of Port Stephens respectively.

The accumulated evidence, including that gained during 1950-51, shows the distribution of striped tuna along the east coast, in relation to area and season, to be generally as follows: in late winter and early spring the major schools are congregated between the Sydney and Port Macquarie areas; in late spring and early summer between Bass Strait and Sydney; in late summer and early autumn between the mid east coast of Tasmania and southern New South Wales; in late autumn and early winter between southern New South Wales and Sydney.

IV. Fish Catch in Relation to Temperature

Table 1 shows the number of fish caught at the different surface temperatures, the number of line-hours trolled at these temperatures, and the catch per line-hour trolled at the different temperatures for each month of the cruises.

Figure 1 is compiled from data shown in Table 1. From the graphs in Figure 1 it is seen that tuna were taken over a range of temperature of 14.9-21°C. in an investigated range of temperature 14-23°C. Within this range it is seen that most fish were taken between 15.5 and 19.5°C. with the peak between 16.0 and 18°C.

Figure 1, *A*, *B*, and *C*, is compiled from data on fish caught and temperatures taken over areas of 5°, 9°, and 7° of latitude respectively, which areas, according to trolling results, delimited the boundaries of the population at stated seasons of the year.

The slightly higher catch per line-hour at 19.5°C. in Figure 1 *B* can be explained in part by the fact that investigations in Tasmanian waters were concluded in mid April and transferred to the southern New South

TABLE 1

CATCH IN RELATION TO TEMPERATURES AND LINE-HOURS TROLLED

Temperature (°C.)	Cruise 5			Cruise 7			Cruise 8		
	Month	Catch/ Line-hours	Catch per Line-hour	Month	Catch/ Line-hours	Catch per Line-hour	Month	Catch/ Line-hours	Catch per Line-hour
14.0-14.9	Sept.	0/14		Feb.	0/0		June	0/0.5	
	Oct.	0/5.5	0/19.5 = 0	Mar.	0/0	12/18.5 = 0.7	July	0/0.5	0/2.5 = 0
	Nov.	0/0		Apr.	12/18.5		Aug.	0/1.5	
				May	—				
15.0-15.9	Sept.	13/15.5		Feb.	0/2		June	0/0	
	Oct.	0/7.5	13/23 = 0.57	Mar.	16/5.5	111/29 = 3.8	July	0/0	141/30 = 4.7
	Nov.	0/0		Apr.	95/21.5		Aug.	141/30	
				May	—				
16.0-16.9	Sept.	55/35		Feb.	36/13.5		June	0/0.5	
	Oct.	11/17.5	71/60.5 = 1.2	Mar.	148/19	559/60.5 =	July	0/1	86/21 = 4.1
	Nov.	5/8		Apr.	375/28	9.25	Aug.	86/19.5	
17.0-17.9	Sept.	95/38		Feb.	93/26.5		June	0/1.5	
	Oct.	170/15.5	285/75 = 3.8	Mar.	173/31.5	282/66.5 = 4.2	July	15/15	116/26 = 4.5
	Nov.	20/21.5		Apr.	16/8.5		Aug.	101/9.5	
18.0-18.9	Sept.	103/32		Feb.	40/24		June	0/4.5	
	Oct.	13/2.5	130/49 = 2.7	Mar.	8/18		July	1/19	25/28 = 0.9
	Nov.	14/13.5		Apr.	38/1.5	105/48 = 2.2	Aug.	24/4.5	
				May	19/4.5				
19.0-19.9	Sept.	16/5		Feb.	4/6		June	11/8	
	Oct.	0/0	26/21 = 1.24	Mar.	0/3.5	88/33.5 = 2.5	July	14/18	25/26 = 0.96
	Nov.	10/16		Apr.	31/14.5		Aug.	—	
				May	49/9.5				
20.0-20.9	Sept.	0/0		Feb.	9/4		June	4/13	
	Oct.	0/0	0/4.5 = 0	Mar.	0/0	26/19.5 = 1.33	July	1/25	5/38 = 0.2
	Nov.	0/4.5		Apr.	0/1.5		Aug.	—	
				May	17/14				
21.0-21.9	Sept.			Feb.			June	0/6	
	Oct.			Mar.			July	0/2	0/8 = 0
	Nov.			Apr.			Aug.		
				May			June		
22.0-22.9	Sept.			Feb.			July	0/9	0/9 = 0
	Oct.			Mar.			Aug.		
	Nov.			Apr.					

Wales area. At this time of the year, in the latter area, surface water temperatures lower than 17.5°C. did not exist and it also appeared that

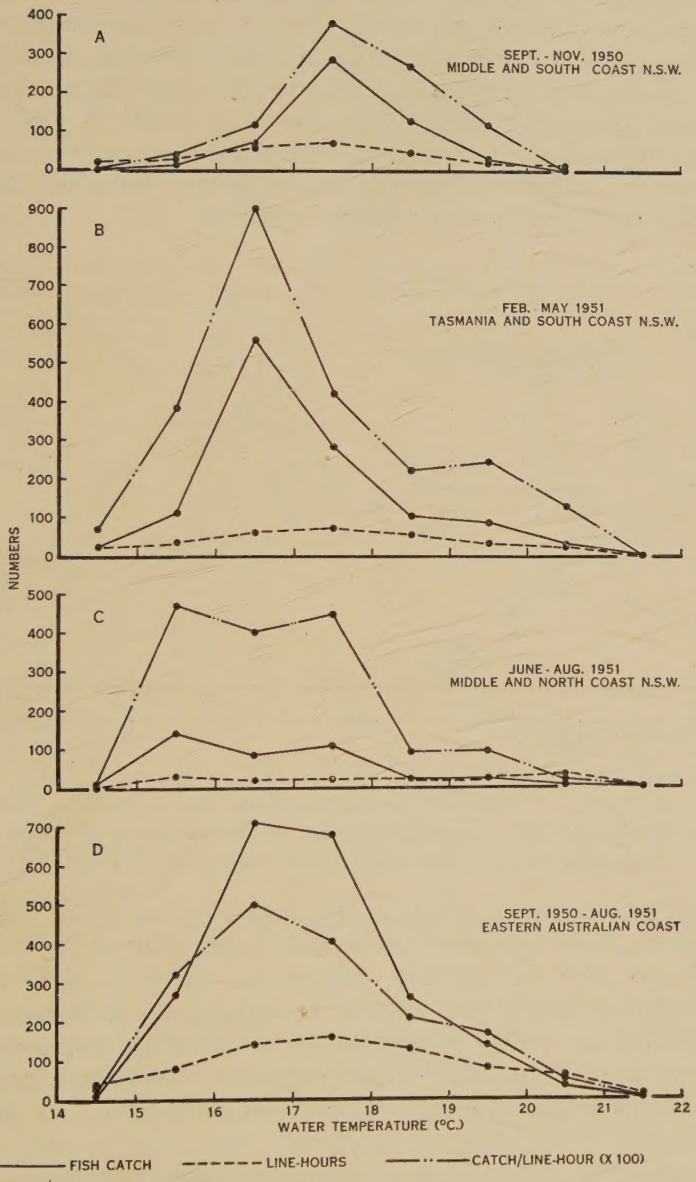

Fig. 1.—Numbers of fish taken, number of line hours fished, and mean number of fish taken per line hour, plotted against water temperatures for localities mentioned (*A*, *B*, and *C*), and for all localities combined (*D*).

the northern limit of distribution in this month was being closely approached.

In Figure 1 *C* the drop in catch rate towards 18 and 19°C. does not give, in the author's opinion, a true representation of abundance, owing to the tuna in the areas with temperatures of 18-19°C. showing reluctance to take the lure, for many schools were investigated without any fish being caught. This reluctance may be related to a change in the tuna's diet. Most of the fish caught in June, July, and August at temperatures of from 15 to 18°C. were taken in water south of Port Hacking, New South Wales, and their diet consisted of euphausians, whilst fish taken in warmer waters (18-19°C.) to the north were feeding only on small fish (larval pilchards and anchovy mainly).

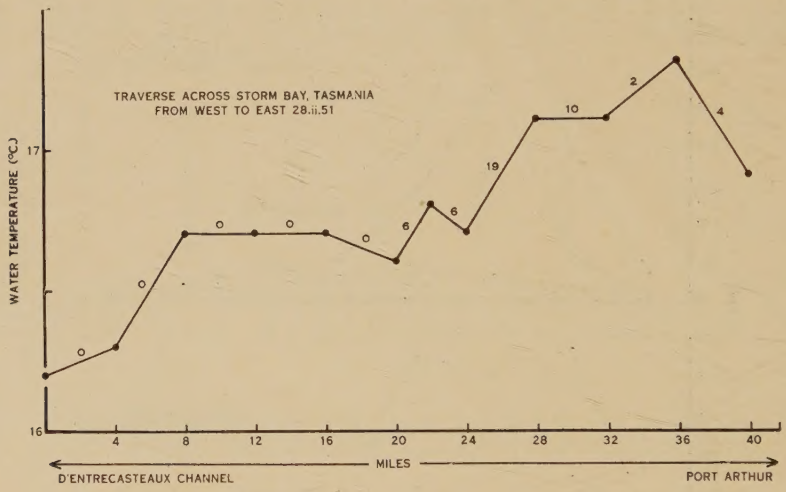

Fig. 2.—Catch in relation to temperature on a traverse across temperature 'fronts'. Numbers between points on the graph show the number of fish taken between temperature readings.

The composite graph (Fig. 1 *D*), based on data for most of the 1950-51 season, shows the most favourable temperatures for fishing to be between 16 and 18°C. for eastern Australian waters as a whole.

At an early stage of the 1950-51 investigations it became apparent that most fish were being caught within a specific temperature range, and that even within this latter small range the tuna struck most often at still more specific yet slightly varying temperatures, e.g. 16.7-17.1°C. (Fig. 2).

This feature was exhibited on many occasions and was exploited to find the areas in which tuna occurred. It was found that the increase in catch rate coincided with 'fronts' where temperature changed slightly. When these fronts were crossed and the ship passed into areas of temporarily stable temperature the catch rate fell (Fig. 3).

Traverses to 40 miles out from the coast into the eastern Australian current revealed that there is an overall rise in temperature, by small

increases with increasing distance from the coast, until a steady maximum is reached. This rise varied from as much as 4°C. to as little as 1°C., the higher variations taking place during the spring, summer, and early autumn months.

On all traverses, with the exception of one, trolling resulted in fish being caught only within certain temperatures. That is to say, the ship passed through the favourable temperature zone where fish were caught, and thence into waters of higher or lower temperatures, depending on direction of steaming in relation to the coast, where the catch rate fell to zero.

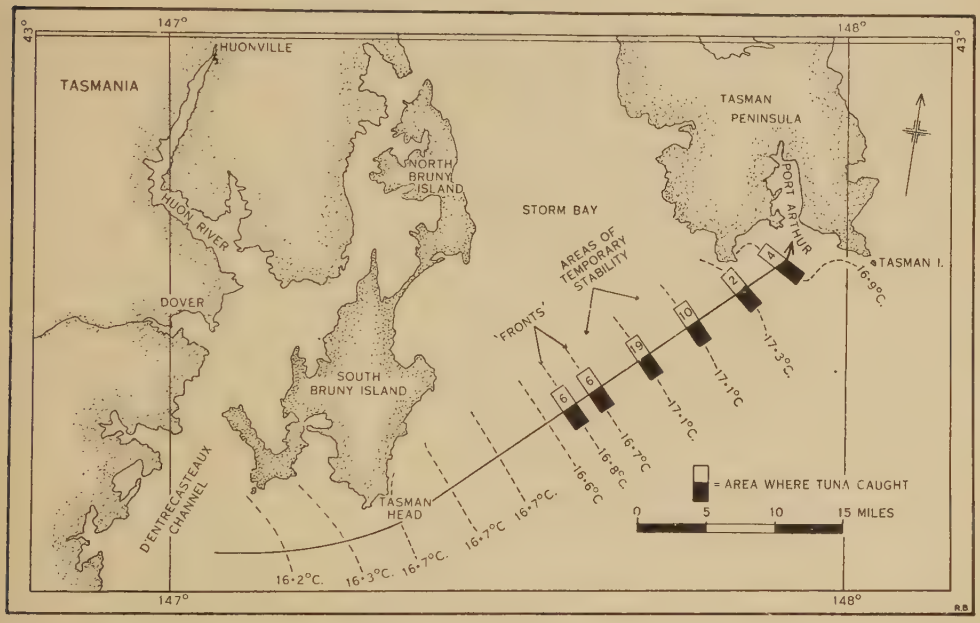

Fig. 3.—Diagrammatic sketch of striped tuna catch in relation to temperature 'fronts', 28.ii.51, shown in Figure 2.

This apparent preference for certain temperatures in areas investigated led to the conception that seasonal distribution of the tuna could be correlated with seasonal change in temperature.

During the course of investigations in Tasmanian waters in the autumn months of 1951, the hypothesis of temperature influence became strengthened when striped tuna were trolled 140 miles further south than St. Helens in waters at 18°C. The question arose: Why do the fish penetrate normally only to the St. Helens area when their staple food (euphausians) is quite abundant further to the south?

Until this stage of the 1950-51 investigations (March 1951), striped tuna had not been taken in waters of less than 15.4°C., and even in waters of this temperature they were definitely few in number. In April, after

the temperature had dropped suddenly and movement north had commenced, a few stragglers were caught in waters at 14.7°C. If 15.4°C. is

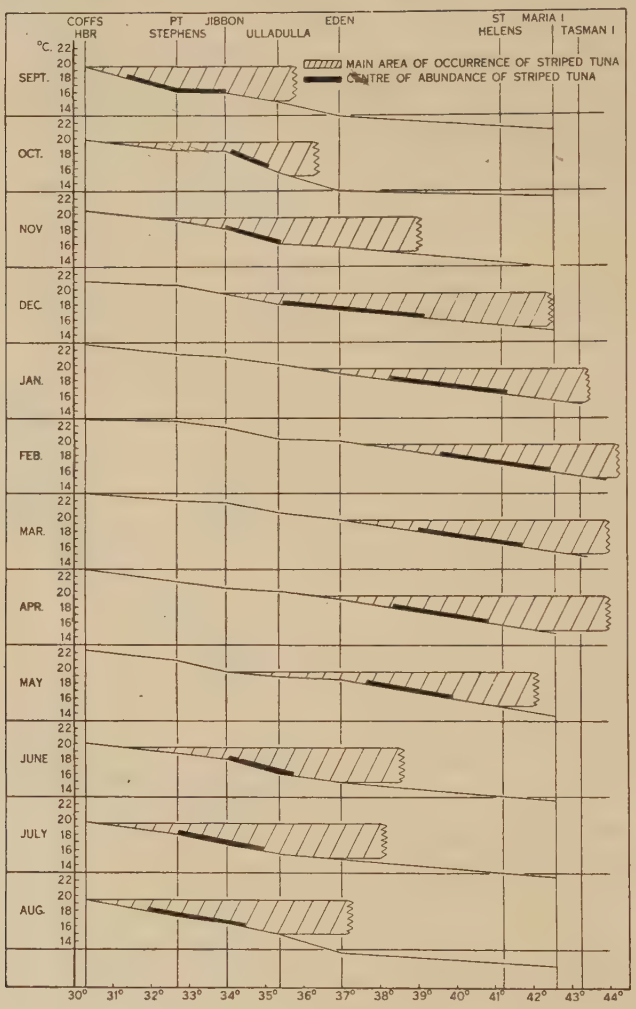

Fig. 4.—Distribution of striped tuna along the south-eastern Australian coast in relation to surface temperature during the year. Average monthly temperature calculated (according to availability of data) for each of the hydrology stations where names are shown and plotted; the sloping line shows change in temperature with latitude. The hatched areas (15.0-19.0°C.) indicate the main areas of occurrence, and blacked-in areas (16.0-18.0°C.) denote the centre of greatest abundance (one for each month).

taken to represent the lower limit of their tolerance range, the probable significance of the non-occurrence of striped tuna beyond the St. Helens

area can be seen, because the average temperatures for the late summer to mid autumn months of the St. Helens, Maria Island, and Tasman Island areas are 15.8°C., 15.3°C., and 14.9°C. respectively (data from Hydrology Section, Division of Fisheries, C.S.I.R.O.).

Now, in 1951, the average temperatures for the same months and areas were 17.4, 16.6, and 16.6°C. respectively, and striped tuna were abundant in the Tasman Island area. It seems that the exceptionally high water temperatures, which were even as high as 18°C. 40 miles south of Tasman Island in March 1951, constituted favourable conditions for the appearance of the striped tuna in this area.

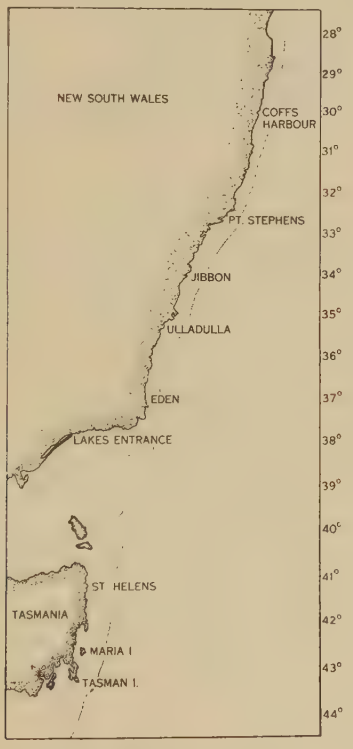

Fig. 5.—Localities named in Figure 4.

In April the surface water temperature fell quite suddenly (3°C.) in the Tasman Island and to a lesser extent (1.5-2°C.) in the Maria Island area, coincident with the onset of the seasonal westerly winds. Associated with this sudden temperature change there occurred an abrupt termination of catches in the Tasman Island area and a falling off in the catch rate in the Maria Island area; and at the same time the centre of abundance of striped tuna moved further north along the coast.

The northern limit of the striped tuna distribution again appeared to be influenced by temperature. In late winter and early spring of 1951

the tuna ranged as far north as Port Macquarie in abundance; they possibly ranged further north, but investigations were unfortunately halted, owing to uncontrollable circumstances, before the critical period when apparent movement south commenced.

Nevertheless it appears that the movement south coincides with increasing temperatures in the north, regardless of the fact that the main food of the tuna (larval pilchards spawned during the winter months) is still abundant in the area and of a size that is most acceptable as food. The temperature that appears to limit the northern penetration of striped tuna is about 20.5°C.

During late spring, summer, and autumn there is a progression of the two limiting temperature boundaries (15.4 and 20.5°C.) southward, and in late autumn, winter, and early spring there is a progression northward; there is also a synchronous movement, within these limits, of the striped tuna population on the east coast (Figs. 4 and 5).

V. Acknowledgments

The author gratefully acknowledges the advice and guidance of Dr. H. Thompson and also thanks Mr. M. Blackburn for scrutinizing the manuscript. Temperature data, upon which Figure 4 is partly constructed, were supplied by the Hydrology Section of this Division.

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STUDIES ON THE ECOLOGY OF THE NEW ZEALAND FRESHWATER EELS

I. THE DESIGN AND USE OF AN ELECTRIC FISHING MACHINE

By A. M. R. BURNET*

(*Manuscript received April* 15, 1952)

Summary

A portable electric fishing machine using pulse-modulated D.C. has been developed. Short-finned eels have been shown to occur in three streams in which they have not been previously found. It has been shown that the river population of long-finned eels is not entirely female. Total population densities have been calculated and a comparison is made with the population densities as measured by the baited trap method.

I. INTRODUCTION

The study (Burnet 1952) of the long-finned eel, *Anguilla dieffenbachii* Gray (Griffin 1936), populations reached a stage where, to make any real progress, a more efficient method of capture had to be devised. The problem was how to sample a population, all members of which are hidden in cover during daylight hours and some of which, the smaller ones, remain in cover all the time. Some form of electric machine was, as far as could be determined, the best solution. A study of the different electric machines used, most of which are described by Elson (1950) and Omand (1950), indicated that direct current should be the choice. It appeared, however, that a machine capable of delivering up to 500 V. at 2 A. (1 kW.) would be required. The claims of Kreutzer and Peglow, quoted by Houston (1949), for the use of pulse-modulated D.C. suggested that by this method the same results could be obtained with a very much lower power consumption, and in addition it was claimed that fish are attracted to the positive pole of the machine.

II. THE PHYSIOLOGICAL BASIS

As a first step some experimental work was done to establish the physiological constants and thus the basis for the electrical design of a suitable machine. Three main electrical variables, the shape, duration, and repetition frequency of the pulse, determine the minimum voltage required to stimulate a tissue.

A special machine was built for this preliminary work. Electrodes were placed at the ends of a trough 14 in. wide, 7 in. deep, and 100 in. long. The water depth was adjusted to give a convenient resistance. The electric current was thus contained within an even, rectangular cross section

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and therefore the voltage gradient was reasonably uniform. Most of the experiments were done using adult *Galaxias attenuatus* as they showed a well-defined and reproducible paralysis point and also recovered rapidly, provided the voltage had not been taken too far beyond the paralysis point or applied for too long. It was much more difficult to get reproducible results with eels, and also at the time the experiments were done a sufficient number of small eels could not be obtained.

(*a*) *Shape of Pulse*

Theoretically a rectilinear pulse is the ideal shape. However, in practice, it is very much simpler to use a condenser discharge. Evans

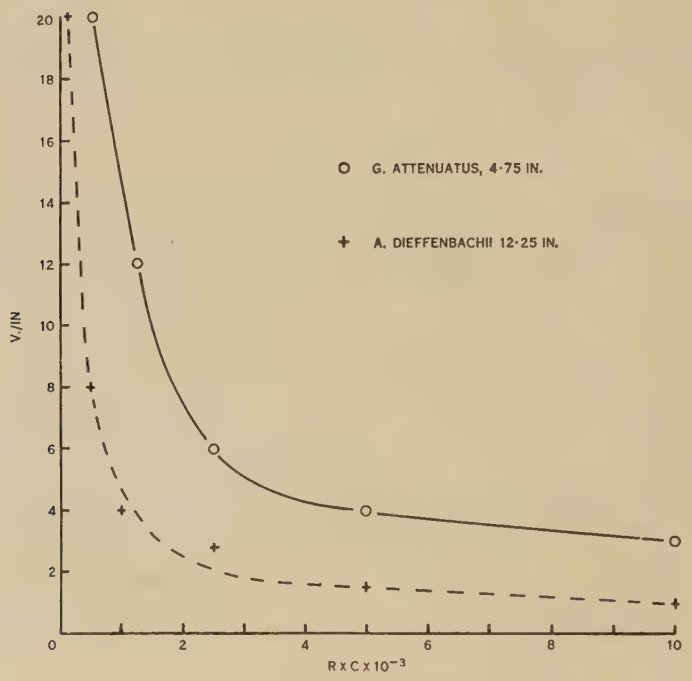

Fig. 1.—Relation between voltage gradient required to paralyse and the pulse length used. For convenience of calculation the pulse time is expressed as resistance in ohms × capacitance in farads × 10^{-3}. To convert to the equivalent rectilinear pulse time in milliseconds, multiply by 0.37.

(1945) states, "It has been shown that a discharge from a condenser charged to a given voltage is equivalent to a rectilinear constant current of duration $0.37RC$ sec., at the same voltage. (R = resistance of circuit in ohms; C = capacity of condenser in farads)." There would thus be some power saving (maximum 25 per cent.) in the use of a rectilinear pulse shape, but in practice the difficulty of obtaining this shape far outweighs its advantage.

(*b*) *Duration of Pulse*

Using a repetition frequency of 15 c/s., the voltage gradient necessary to produce paralysis was determined for various pulse lengths. The voltage gradient plotted against pulse time (Fig. 1) is a rectangular hyperbola similar to that illustrated in Evans (1945). The relevant constants are shown in Table 1. The galvanic threshold or rheobase is the minimum continuous D.C. voltage required to produce contraction of the tissue (i.e. paralysis). There is some evidence that a constant potential difference between the head and tail of the fish will produce paralysis, irrespective of the length of the fish. Thus the longer the fish the lower the potential gradient required.

The chronaxie is the shortest duration of a current of twice the rheobasic voltage that will stimulate the tissue. The shorter chronaxie

TABLE 1

ELECTRO-PHYSIOLOGICAL CONSTANTS

Fish	Length (in.)	Rheobasic Voltage Gradient (V./in.)	Head to Tail Potential (V.)	Chronaxie (msec.)
Galaxias attenuatus	4.75	2.0	9.5	1.9
Anguilla dieffenbachii	12.25	0.6	7.3	3.0
Anguilla dieffenbachii	7.10	1.0	7.1	Not measured

time for *Galaxias*, indicating a higher speed of action of the tissue, could probably be correlated with the different methods of swimming of the two species.

(*c*) *Repetition Frequency*

The effect of repetition frequency on the voltage required to paralyse the smallest fish for which the machine would be used is shown in Figure 2. Kreutzer and Peglow (see Houston 1949) claimed that, if the frequency of the pulse is matched to the natural wriggling frequency of the fish, it will be caused to swim up to the positive electrode. The author has not observed this to occur with eels although salmonids appear sometimes to react in this way.

While only a small amount of experimental work was done it has been sufficient to enable suitable equipment to be built.

(*d*) *Summation of Stimuli*

The pulse technique so far investigated has been based upon the summation of contractions. If the time interval between stimuli is reduced to about twice the chronaxie time, then subliminal stimuli will be summated to produce an effect. An investigation of the voltage and pulse times required to produce paralysis at the summation frequency of about 200 pulses/sec. may lead to useful results.

III. Electrical Requirements and Design of Machine

(*a*) *Voltage Output*

The results obtained by overseas workers suggest that an output of at least 500 V. would be necessary. It has been found that peak pulse voltages of between 600 and 750 V. are satisfactory in practice.

(*b*) *Repetition Frequency*

From Figure 2 the power required to produce paralysis at the various frequencies can be calculated and it is found to be a minimum at about 20 c/s. While the first machine built had a number of repetition frequencies, the best results were obtained at about 20 c/s.

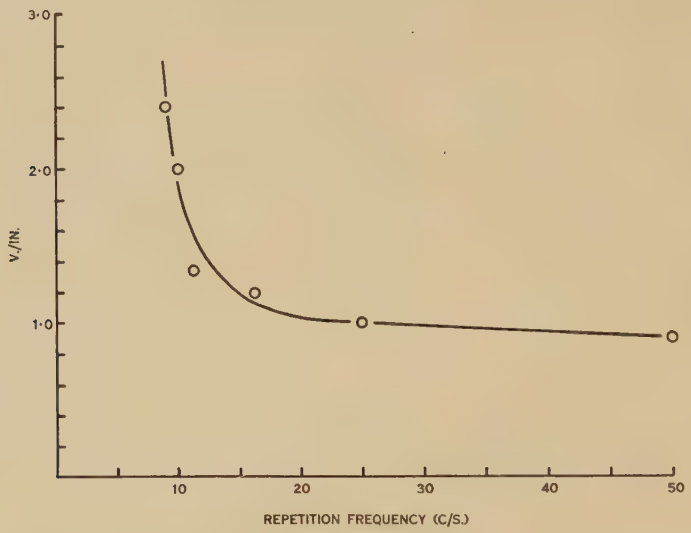

Fig. 2.—Effect of repetition frequency on the voltage gradient required to paralyse. The equivalent pulse time used for this experiment was approximately 2 msec.

(*c*) *Pulse Length*

From Figure 1 it can be seen that the maximum effect is obtained from a given output voltage when the operating point is on the flatter portion of the curve. A better power efficiency is also obtained with the longer pulse. Good results are being obtained with a machine that has a pulse time equivalent to a rectangular pulse of about 1 msec. The smallest eels encountered, $3\frac{1}{2}$ in. long, can be paralysed within about 1 ft. of the electrode. However, for use with salmonids a much stronger field is necessary and an equivalent pulse time of at least 2 msec. should be allowed.

(*d*) *Factors affecting Pulse Length*

Load resistance must have a large effect on the range of the machine. It is necessary to make measurements of circuit resistance, using an

electrode set-up of the type decided upon, in the various types of streams in which the machine is to be used. The water in most of the streams fished by the author has a specific resistance of about 5000 ohms/in. cube, and with the particular electrode system used the output resistance is about 250 ohms. Thus to obtain a pulse time of 2 msec., RC is 0.0054, and C is then 20 μF. (approx.).

(*e*) *Power Requirements*

The amount of power required to drive this system = $\frac{1}{2}NCV^2$ watts, where N = repetition frequency in cycles per second, C = capacity in farads, and V = output voltage. If C = 20 μF., N = 20 c/s., and V = 700 V., then power required = 100 W.

With this length of pulse the results obtained are approximately equal to those that would be obtained with a continuous D.C. machine of half the output voltage. This would use 500 W. There is therefore a

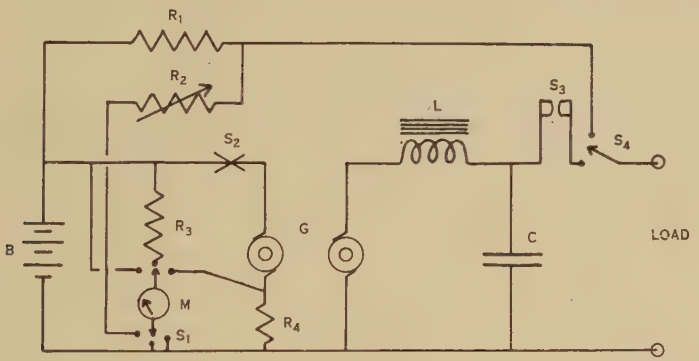

Fig. 3.—Circuit diagram of machine. *B*, battery. *C*, pulse-forming capacitor; *G*, genemotor; *L*, resonant charging inductance; *M*, meter; R_1, reference resistor for measurement of field resistance; R_2 meter zero set; R_3 meter shunt for battery voltage; R_4, meter shunt to read battery current; S_1, meter selector switch; S_2, battery on-off switch; S_3 mechanical discharge switch (see Fig. 4); S_4, change-over switch for resistance measurement (could be ganged with S_1).

considerable saving in power, even allowing for our machine not being 100 per cent. efficient. This low power requirement makes a small portable machine driven from an accumulator a practical possibility, and, in any case, a suitable petrol-motor driven generator would be quite small.

(*f*) *Circuit of Machine*

The simplest method of producing a pulse is by using a capacitor discharge. Inductance charging of the capacitor is considered to be desirable in spite of the weight of the inductance, as resistance charging cannot be more than 50 per cent. efficient.

If the circuit shown in Figure 3 is made resonant at half the pulse-repetition frequency, then the output voltage from the capacitor will be twice the input voltage from the genemotor. To attain this, however, the Q of the circuit must be high: if $Q = 10$, efficiency becomes 92 per cent.

To calculate the resonant frequency, if R is small compared with $(L/C)^{\frac{1}{2}}$, then

$$F = (1/LC)^{\frac{1}{2}}/2\pi,$$

and, for a frequency $F = 10$ c/s. and $C = 20$ μF., then $L = 12.7$ H.

The resistance of the charging circuit must now be considered:

$$Q = 2\pi FL/R,$$

where R = effective resistance of genemotor, and inductance L. Therefore total permissible resistance for a Q of 10 is 80 ohms. The genemotor should thus be capable of handling 100 W. and have an output of 370 V. (approx.) and an effective resistance of not more than, say, 60 ohms. This allows a further 20 ohms for the resistance of the inductance.

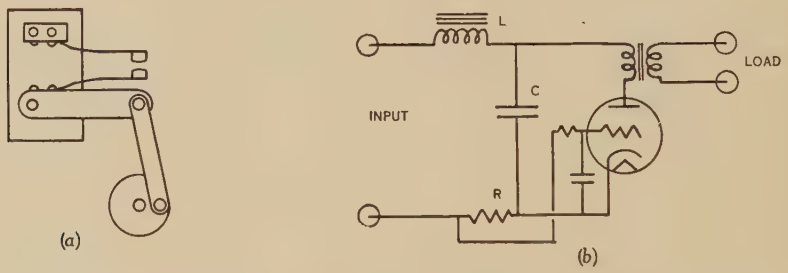

Fig. 4 (a).—The mechanical switch S_3. The simple harmonic motion of the contacts should keep contact bounce at a minimum. "Elkonite" relay contacts of 5 A. rating are the best available to the author.
(b).—Circuit diagram with the mechanical switch replaced by an electronic one. This would give better service over long periods of operation (e.g. for electric barriers), but it has a lower power efficiency than that of Figure 3.

The switch S_3 is best mechanically operated by the genemotor shaft, via a reduction gearing. It requires to be closed for only slightly longer than the discharge takes. The major problem to be overcome in the design is contact bounce and the resultant arcing of the contacts during the discharge. The type of switch being used is shown in Figure 4(a). It has been found that the pitting of the contacts, due to arcing, can to a large extent be overcome if the polarity of the contacts is changed periodically.

The capacitors require to be rated for A.C. use, to ensure that they can dissipate the heat generated in them. Electrolytic capacitors are not

suitable, and oil-filled capacitors with only a D.C. rating may not be satisfactory.

Where more power is available, and a maximum of efficiency is not required, it would be possible to replace the mechanical switch by electronic switching. A suitable circuit using a thyratron is shown in Figure 4(*b*). As before, the capacitor *C* charges through inductance *L*, and is resonant at half the recurrent frequency. Resistor *R* provides bias to hold off the thyratron while the charging current is flowing, and when the current falls to a low value at the end of the charging cycle, the thyratron fires.

Only the basic essentials of the electronic design have been given. The construction of a machine to suit individual requirements should be done in consultation with an electronics engineer.

IV. The Machine and Method of Use

The machine at present in use has a 20 W., 480 V. genemotor, and will produce a pulse output of about 40 W. at 630 V. for an input of 85 W. There are two main causes of this low efficiency. First, there are the normal genemotor losses and little can be done to improve on these. Second, the genemotor has a high output resistance, and thus the efficiency of the charging circuit is low. An attempt is now being made to obtain a larger genemotor with a lower resistance and thus improve the charging efficiency. In addition to the basic essentials already described, a meter is incorporated to measure battery voltage, current, and load resistance. A check of the load resistance is made every time the machine is set up and thus an unexpected value of load resistance or a bad connection can be detected.

The power is supplied by a 24 V. unit made up of four 6 V., 17 A.-hr. "motor cycle" batteries. The capacity of this unit is sufficient for operation for 5 hr. when the genemotor is drawing 85 W.

It would appear that ideas of fisheries biologists on the behaviour of electric fields in water are very hazy. Fisher (1950) for example, states, "Generally speaking, if the distance between the electrodes is doubled, the resistance is doubled." While the author has not done any exhaustive tests, it can easily be shown that this statement only holds when the distance between electrodes is less than the diameter of the electrodes. When the electrodes are small compared with the spacing between them, most of the resistance is "end effect", i.e. close to the electrode, and correspondingly the voltage gradient is high close to the electrodes and low half-way between.

The lines of current flow in the water follow the same pattern as the lines of force between magnetic poles. Between the electrodes the "field" bulges out to many times the cross section area of the electrodes. There is thus a lower current density per unit area, and by Ohm's law the voltage gradient per foot is correspondingly lower. Resistances

measured with 6-in. square electrodes in water of approximately 5000 ohms/in. cube resistivity gave the following results:

6 in. spacing—230 ohms; 4 ft.—340 ohms; 10 ft.—360 ohms; 20 ft.—370 ohms. A single electrode with earth return (a piece of wire netting, 2 ft. 6 in. by 5 ft., placed on the stream bed) gives a resistance of 250 ohms, and this remains fairly constant for spacings of up to 100 yd., except when the two are within a few feet.

Observations on the stunning of eels, using a 6-in. square electrode, earth return system, and 600 V. peak, suggest that the voltage gradient is of the order:

1 ft. from electrode = 8 V./in.
3 ft. from electrode = 4 V./in.
10 ft. from electrode = 1 V./in.

A study of the data presented by McMillan (1928) will also show the type of results to be expected.

For the study of eel populations the author has found an earth return system to be very suitable. As there is only one moving electrode, fewer operators are required than with the two-electrode system. The best earth was found to be a piece of galvanized wire netting, $2\frac{1}{2}$ ft. by 5 ft., placed on the bed of the stream. As this electrode is much larger than the positive one, little of the output voltage is dissipated around it. It must be remembered, however, that this system will not work satisfactorily if the ground resistance is high (e.g. rock). The positive electrode is a 6-in. square of $\frac{1}{4}$-in. brass rod, with two cross-pieces. This is attached to a 5 ft. waxed wood handle. Connection to the machine is via 100 yd. of 7/0.029 T.R.S. cable with a spring release switch on the handle. The cable is run out from a drum on the bank and dragged behind the operator. While this is not as convenient as the drum carried by the operator (e.g. Wolf machine), it is thought to be much safer. The operator also wears "electric linesman's" rubber gloves as an extra precaution. These prove very useful in the eel work as they enable the operator to lift small eels out from between stones, under logs, etc. while they are paralysed. The assistant, seen picking up eels as they drift out from under stones (Plate 1), is quite safe provided he has a good, waterproof pair of thigh boots.

In practice, 100 yd. of stream, all of which can be waded or reached with the electrode, is selected. A fine-mesh ($\frac{1}{2}$-in. stretched mesh) net is set across the lower end of the area and the operator and assistant work from the upstream end of the area down to the net. This appears to be the most satisfactory practice for eels as they mainly tend to move off downstream when disturbed.

A number of reactions have been observed. Some of the eels are frightened off downstream when in the periphery of the field and are not seen by the operators until collected in the stop net. Many of the small eels (less than 10 in.) are frightened out quite close to the operator and

he can move the electrode close enough to paralyse them. A large proportion are paralysed in cover and may in time be carried out by the water current. A number of those not carried out often swim out after the operator has moved on. With very deep cover it has often been noticed that the yield is much better on the second run. Each area was covered at least twice and, where possible, three times. While this technique has proved very satisfactory for eels it is thought that a two-electrode system, with its resultant more even field, may be more suitable for salmonids, particularly if worked upstream. The voltage gradient near the electrodes will not be as high as with the single electrode and earth return. However, the load resistance will be higher and consequently the pulse duration will be longer. This will, to some extent, compensate for the lower voltage gradient.

No measurements have been made of the mortalities resulting from the use of this machine. It would appear, however, that a fairly large percentage of the eels are killed as a result of being exposed to a strong electric field for times of up to 5 min.

The machine has been used on three streams in the Wellington district; the Horokiwi River, the Wainui-o-mata River, and the Mangaroa River.

V. Efficiency

In all areas fished at least two runs were made. The results for each run are shown in Table 2, and the rate of catch, P, has been calculated as was done for baited traps (Burnet 1952). Most of the series of runs give a very good fit to an exponential regression and the values of P obtained agree reasonably well. There is some indication of correlation between the width of the river and the efficiency. The Wainui-o-mata River, which averages over twice the width of the Horokiwi River, has a lower value of P. There is no conclusive evidence of different efficiencies for different-sized eels.

A single run with the electric machine has taken between 26 and 71 per cent. by number of the population, with a mean value of 43 per cent. Thus, on the average, 67 per cent. can be removed with two runs and 81 per cent. with three runs.

VI. Population Constitution

Both the long-finned and the short-finned species of eel have been found in all areas so far examined and the relative numbers are set out in Table 3. In each river, area 1 is the head waters of the river system.

These occurrences of short-finned eels, *Anguilla australis schmidtii* Phillipps (Griffin 1936), are an extension of the distribution as stated by Cairns (1941). However, as most of the short-finned eels caught in the upper waters were less than 12 in. long (Fig. 5) and live a cryptozoic life, they would not normally be apparent.

TABLE 2
RESULTS OF ELECTRIC FISHING

River	Area No.	Date	Width (ft.)	P	n	$1-(1-P)^n$	Area (ac.)	Long-finned Catch (lb.)	Short-finned Catch (lb.)	Total Catch (lb.)	Total Possible Yield (lb./ac.)
Horokiwi	1	29.i.52	5	0.71	2	0.92	0.03	5.22	0.94	6.16	223
	2	28.i.52	6	0.45	4	0.91	0.04	13.39	3.75	17.14	472
	3	6.ii.52	13	0.35	3	0.72	0.12	51.62	2.68	54.30	630
	4	29.i.52	18	0.29	2	0.50	0.20	50.08	2.10	52.18	522
	5	18.i.52	15	0.37	3	0.75	0.07	47.48	0.20	47.68	910
	6	5.ii.52	16	0.46	3	0.83	0.13	16.84	2.97	19.81	183
	7	8.i.52	14	0.48	2	0.86	0.06	5.87	3.68	9.55	185
Mean			12	0.44							470
Wainui-o-mata	1	21.ii.52	11	0.45	2	0.62	0.08	18.90	0.33	19.23	390
	2	18.ii.52	26	0.39	3	0.77	0.14	29.08	0.36	29.44	273
	3	20.ii.52	50	0.38	2	0.62	0.31	79.66	1.11	80.77	422
	4	11.iii.52	23	0.35	3	0.72	0.13	29.57	0.01	29.58	315
	5	13.iii.52	28	0.26	3	0.60	0.20	4.92	0.07	4.99	42
	6	12.iii.52	23	0.35	3	0.72	0.10	18.08	0.02	18.10	252
Mean			27	0.36							285
Mangaroa	1	7.ii.52	15	0.50	2	0.75	0.10	36.60	1.08	37.68	503
	2	19.ii.52	14	0.71	3	0.98	0.09	26.45	0.44	26.89	305

Hobbs (1947) found that in Lake Ellesmere the male migrant short-finned eels ranged in length from 15 to 23 in. (mean 18.9 in.) and the females from 22 to 32 in. (mean 27.1 in.). It would thus appear that the fast-flowing shingle-bed streams examined are a suitable habitat for short-finned eels when small. The larger ones probably move into lakes, lagoons, or sluggish streams to grow to full maturity.

TABLE 3

DISTRIBUTION OF SHORT-FINNED EELS

Area	1	2	3	4	5	6	7
Horokiwi River							
Distance from sea (miles)	8.0	7.3	3.2	2.8	2.5	1.8	0.3
Number in sample	31	93	127	169	75	124	121
Percentage short-finned	52	55	33	24	11	48	88
Wainui-o-mata River							
Distance from sea (miles)	18.8	8.8	4.9	4.2	3.5	2	
Number in sample	34	81	159	60	54	143	
Percentage short-finned	21	2	1	3	4	1	
Mangaroa River							
Distance from sea (miles)	24	24					
Number in sample	30	34					
Percentage short-finned	37	32					

VII. Distribution of Male Long-Finned Eels

Cairns (1941) states, "It has been recognized fairly generally overseas (Gilson 1908; Tesch 1928; Hoover 1936) that the male eels do not frequent fresh water. This fact is supported by the evidence presented for the distribution of New Zealand eels."

The author has, however, caught during this study a number of long-finned male migrants; one from area 4 of the Horokiwi; one from area 2, and four from area 4 of the Wainui-o-mata River. This has led to a re-examination of the literature. Hoover (1936), in a general account of the life history of the eel, states, without any supporting evidence, that all American freshwater eels are females. The paper by Gilson (1908) is not at present available to the author. Tesch (1928) records 28 per cent. males in unspecified inland waters. Bertin (1942) states: "*Loi généralement formulée*; les mâles se rencontrent dans les estuaires et les lagunes littorales; les femelles se trouvent uniquement en eau douce. A mesure que l'on s'éloigne de la mer, le nombre des mâles diminue et celui des femelles augmente." Evidence for and against this rule is also presented. It is definite, however, that in both Europe and New Zealand male eels do occur in fresh water. Consequently, there may be an annual seaward migration of mature, migrant, long-finned male eels of between 20 and 30 in. long. If this migration involves a significant proportion of the population the shape of the length frequency curve will be affected.

VIII. Length Frequency Distribution

The length frequency distribution (Fig. 5) of the long-finned eels caught by this new technique is the most complete picture of an eel population so far obtained. The differences between the Horokiwi and Wainui-o-mata Rivers indicate a number of interesting points that require further study.

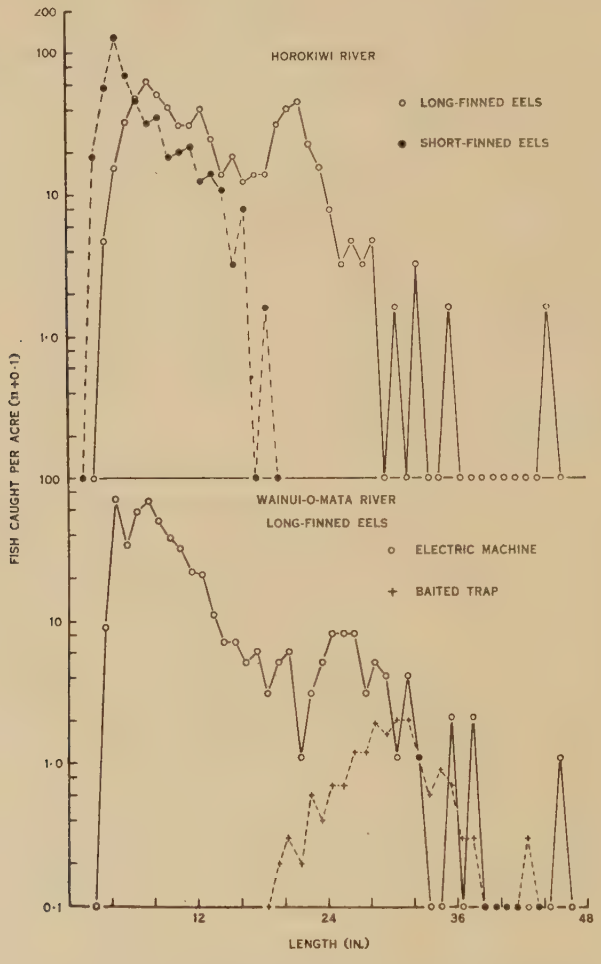

Fig. 5.—Length frequency distribution of eels caught in the Horokiwi River and the Wainui-o-mata River.

The absence of a peak at 4½ in. in the Horokiwi and the fact that it occurred only in areas 3 and 4 of the Wainui-o-mata indicates that a wave of upstream migrants was 4-5 miles from the mouth of the Wainui-o-mata River, but had not begun in the Horokiwi River. Short-finned eels 4½ in. long occur in the head waters of both streams and thus the upstream migration of short-finned eels had occurred at the time of sampling. In

confirmation of this, the caretaker of the Wainui-o-mata Waterworks (approximately 18 miles from the sea) had seen small eels on the dam during January. The next peak in the Horokiwi River—21 in., and Wainui-o-mata River—25 in., is thought to be an effect caused by the selection of areas of relatively good eel cover for investigation. That the peak occurs at a shorter length in the smaller stream is believed to be an indication that it is a cover effect. The Horokiwi River has very little cover for eels over 30 in. long. As it is not possible to work large areas of river with the facilities available, a complete picture can only be obtained by estimating the relative amounts of cover of various types and extrapolating the results so far obtained.

For comparison the results obtained by the use of baited traps are also shown in Figure 5. An estimate has been made of the proportion of the eels caught by the electric machine that would have been taken in baited traps. It was assumed that all fish of over 30 in. would be caught and that those below 30 in. would be caught in the proportions indicated by relative numbers of each size-group caught by the two methods (using a smoothed version of both curves), e.g. in the 28-in. group there are approximately 3.5 fish caught by the electric machine and 1.4 or 40 per cent. caught by the baited trap. The percentage trappable in each size-group is then applied to the weight of fish in each size-group of the electric machine catch, and thus a figure for the total percentage trappable is obtained. The estimate for the Wainui-o-mata River was 42 per cent. by weight of the total population taken in baited traps. The same technique applied to the Horokiwi results indicate that 17 per cent. by weight would be taken. The latter figure can only be taken as very approximate. On the other hand, in rivers with high trappable eel densities, the proportion of eels of over 30 in. may be relatively higher than in the Wainui-o-mata River and thus a greater proportion of the total population would have been taken in baited traps. Thus while care must be taken in extending the results of these preliminary investigations, probably not more than 50 per cent. by weight of an eel population can be removed using baited traps.

IX. Population Densities

All the data on population densities are set out in Table 2. The percentage of the total population caught ($= 1 - (1 - P)^n$) has been calculated from P, and thus the total population densities have been estimated. The mean densities of the trappable population are thus about 80 lb./ac. in the Horokiwi River and 120 lb./ac. in the Wainui-o-mata River. This figure for the Wainui-o-mata River is much higher than that obtained by the use of baited traps (39 lb./ac.) because of the smaller size of the area sampled and the selection of areas with good cover for the larger eels.

Area 6, Wainui-o-mata, was fished with baited traps in 1948 with a yield of 76 lb./ac. The same area fished with the electric machine yielded

252 lb./ac. The range of densities shown in Table 2, 42-422 lb./ac. for electric fishing can also be compared with the range of densities for trapping, 10-185 lb./ac., in corresponding types of water. These figures show that the previous estimate of 42 per cent. of the population being trappable is of the correct order.

It is also of interest to compare the Horokiwi yields with the trout population densities given by Allen (1951). The mean eel population density is higher than the highest trout population density recorded and twice the mean value.

X. Conclusions

A pulse-modulated D.C. electric fishing machine will produce results comparable with continuous D.C. machines of very much larger size.

The machine has proved to be a very useful and efficient tool for the study of eel populations.

The smaller short-finned eels would appear to be more generally distributed than was previously thought.

It is probable that males form an appreciable proportion of the river population of long-finned eels.

Of the total population, rather less than half by weight can be taken in a baited trap.

Total eel population densities are higher than the corresponding trout population densities in the Horokiwi River. All of this eel population feeds to some extent upon the same bottom-fauna insects as do the trout. The feeding habits of the cryptozoic 3-12 in. group have not yet been examined. This group comprises 9 per cent. by weight of the total population. The 12-30 in. group, comprising 77 per cent. of the population, feeds mainly on the same members of the bottom fauna as do the trout. The eels of over 30 in. (14 per cent. of the population) feed to some extent upon the bottom fauna, and are predators on trout and upon the smaller eels. If food supply is a limiting factor for a trout population, then the eel population must be competing with the trout population to a significant degree.

The electric fishing machine should facilitate further investigations on the interrelation of eels and trout populations.

XI. Acknowledgments

The author wishes to thank Mr. T. H. Scott of the Dominion Physical Laboratory, who designed and analysed a number of suitable pulse generator circuits, and also read and criticized the electrical section of the manuscript; Mr. K. R. Allen, who read and criticized the manuscript; and the members of the staff of the Fisheries Research Laboratory who assisted with the field work.

The electric fishing machine in operation. Paralysed eels drift out from their hiding places and are picked up in a hand net. Those that have been frightened downstream are collected in the stop-net. The machine, battery, and reel of cable are on the far bank.

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THE NACREOUS (MOTTLED) GROUP OF THE GOLDFISH (*CARASSIUS AURATUS* L.), WITH AN ANALYSIS OF THE COLOURS SEEN IN THESE FISH

By R. J. AFFLECK*

(*Manuscript received April* 8, 1952)

Summary

The colours of nacreous (mottled) fish are usually mottled but specimens do occur in which only one kind of the black, orange, or yellow chromatophores is present, while some lack pigments over most of the body. The colours appear metallic, pearl, or matt depending on the presence or absence of reflecting tissue in two definite layers. The hues seen in these fish are black, smoke, blue, orange, yellow, blood-red, and silver, which occur singly or in combinations. These hues are produced by black, orange, and yellow pigments in chromatophores, silver reflecting tissue, and haemoglobin in the blood. The presence of a yellow pigment — a carotenoid — is reported for the first time. Although the colour red has been reported no red pigment has ever been described. An intense orange pigment will produce a red effect on a pale blood-red background.

The nacreous (mottled) group of the goldfish is intermediate between the metallic (scaled) and matt (transparent) groups with regard to the amount of reflecting tissue. The colours of these fish may not be used as criteria of the groups.

I. INTRODUCTION

Chen (1928) described how specimens of goldfish may be placed in three groups, which he called scaled, mottled, and transparent. Although his work was confined to varieties with the shape of the wild-type fish, other domesticated varieties also occur as scaled, mottled, and transparent fish.

In the scaled class the scales of the fish appear metallic. Although the scales are as transparent as glass they appear metallic because of a layer of reflecting tissue beneath them. In the head, where there are no scales, the reflecting tissue is situated beneath the dermal bones. Wild-type fish, which are an olive-grey colour, belong to this class.

The transparent class is completely different from the scaled one. The reflecting tissue is entirely, or almost entirely, absent from the body of the fish so that much of the internal structure is visible and the scales are and appear transparent. According to Chen (1928) chromatophores are also almost entirely absent, being restricted to a few isolated patches. In some specimens that he examined only three normal scales (backed by reflecting tissue) were present, while he mentions that some reflecting tissue may be present in a part or the whole of one operculum but never in both opercula.

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In the mottled class the reflecting tissue and colour are very variable. The head may be completely covered with reflecting tissue, or may be transparent over the whole surface, or transparent over only part of the surface. On the body, according to Chen (1928), there are always some normal scales mixed with transparent ones. The number of normal scales found by Chen varied from two to 18 (most frequently between two and 10). In the body wall an inner layer of reflecting tissue, which in the scaled class is masked by the outer layer of reflecting tissue and which is absent in the transparent class, is either complete or covers about two-thirds of the whole surface. Melanophores, xanthophores, and reflecting tissue are always mixed in the characteristic mottled condition and there is a greater number of coloured spots on the dorsal and the latero-dorsal parts of the body than on the ventral parts.

Chen's genetical analysis is as follows:

Transparent class	$T'T'$
Scaled class	TT
Mottled class	$T'T$

T' is incompletely dominant over T.

Matsui (1933) describes four groups of goldfish. The first has normal scales (i.e. each one is backed by a layer of reflecting tissue); the second has all scales transparent (i.e. each scale lacks the backing of reflecting tissue); the third has normal scales and transparent scales arranged in a mosaic; while the fourth contains fish with scales that are backed by reflecting tissue arranged in a net-like manner. The first three groups correspond to Chen's three groups, but the fourth is new, controlled by another pair of alleles, and unknown in England.

Matsui (1934) disagrees with Chen's statement that the colours and the scale characters are controlled by the same gene and states that the mosaic-transparent group (mottled class) may include piebald fish (orange and white) as well as others that are orange all over.

The different names given to the three groups of goldfish have caused much confusion. In 1949 the Goldfish Society of Great Britain decided that the only way to avoid future confusion was to introduce new descriptive terms. It is now apparent that the differences between the groups depend on the amount of reflecting tissue and not on colour or arrangement of transparent scales. After studying the preliminary work of the author the committee of the society decided on the following terms:

Matt group (genotype TT)—fish in which little or no reflecting tissue is present and the general surface of the body has a matt appearance. This group corresponds to the transparent class and the transparency-for-all-scales specimens described by other workers.

Metallic group (genotype tt)—fish in which all scales have a layer of reflecting tissue immediately beneath them, and the general surface of the body has the appearance of polished metal. This group

corresponds to the scaled class and normal scale fish described by other authors.

Nacreous group (genotype *Tt*)—fish in which part, or the whole, of the body has a mother-of-pearl appearance. This group corresponds to the mottled class, mosaic transparent fish, calico fish, tigerfish, scaleless fish, and shubunkins described by other authors.

This nomenclature emphasizes the characteristics of the groups while retaining the original symbol for the gene controlling the group. In

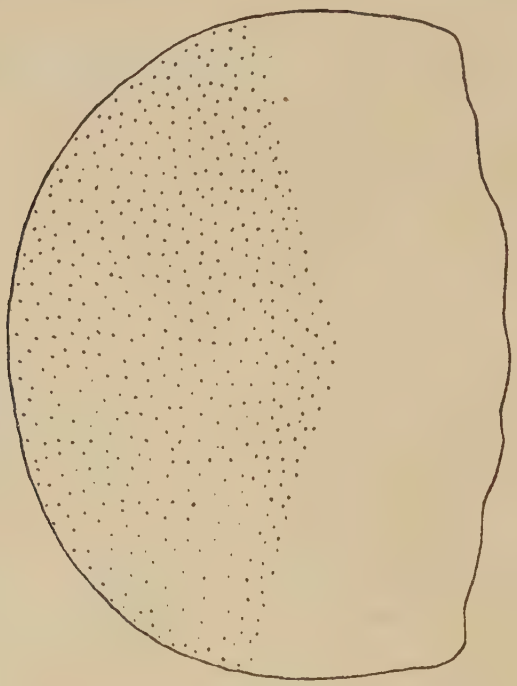

Fig. 1.—Surface view of scale, showing distribution of reflecting tissue in the first layer (seen through the scale).

conformity with modern practice, however, the dominant form is symbolized by *T* and the recessive by *t*. The differences between the groups are discussed later in this paper.

II. Reflecting Tissue in the Nacreous Group

Reflecting tissue, consisting of globular bodies and crystals of guanine, may be present in two definite layers as shown in Figure 2, as well as in the peritoneum, over the gonads, etc. The tissue in the latter regions is not usually visible externally and so has little or no effect on the colours of the fish.

Layer 1 is an interrupted layer which occurs immediately beneath the scales in overlapping regions, as shown in Figure 1 and Figure 2, L_1.

When reflecting tissue is present in this layer it is responsible for the metallic appearance of scales above it. Six scales with a metallic appearance may be seen in Plate 1, specimen 4. In the nacreous group it is not present beneath every scale and may not be present at all. The number of scales that appear metallic varies considerably (0-147 in the specimens examined).

Layer 2 (the inner layer) is situated just beneath the dermis as shown in Figure 2, L_2. Reflecting tissue is always present in this layer although it varies in amount. When not masked by overlying structures, reflecting tissue in this layer has a mother-of-pearl (pearl) appearance (see part of body of fish in Plate 1, specimen 4). It typically occupies about two-thirds of the whole surface but may be increased so that it occupies the whole surface or be reduced to about one-eighth of the whole. It may occur as a continuous sheet or as a number of isolated patches. Unlike the tissue in layer 1, the position of reflecting tissue in the second layer is not controlled by the position of the scales.

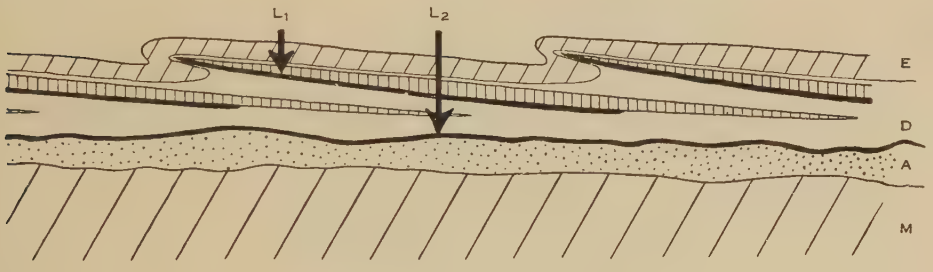

Fig. 2.—Horizontal section through scales and surrounding tissues, showing distribution of reflecting tissue. *E*, epidermis; *D*, dermis; *A*, adipose tissue; *M*, myotomes; vertical hatching — scales; L_1, first layer of reflecting tissue; L_2, second layer of reflecting tissue.

If reflecting tissue is absent the body has a non-shiny, or matt, appearance (see part of body of fish in Plate 1, specimen 4).

When the reflecting tissue is present in the first layer, pigments above it appear metallic except when melanophores above the scales are so densely crowded that they mask everything beneath them. Reflecting tissue in this layer usually masks other structures beneath it. When the tissue is absent from the first layer but present in the second layer, pigments above it have a mother-of-pearl (pearl) appearance except, again, when melanophores above it are so densely crowded that they mask underlying structures. In the second layer, the tissue may not be as dense as it is in the first layer and then melanophores may sometimes be seen dimly through it, when they too have a mother-of-pearl appearance. Pigments without reflecting tissue beneath them appear matt. Reflecting tissue without pigments above it appears metallic silver or pearl silver, according to its position in the fish.

III. Chromatophores and Colour in the Nacreous Group

Chen (1925) described the colours found in Chinese scaled (metallic) varieties and gave particulars of the chromatophore arrangements for producing black, brown, bronze, blue, orange, and white. He mentioned that there are fish with transparent scales (nacreous fish), the colours of which consist of a mixture of different-coloured spots of blue, orange, or black. The blue colour in nacreous fish is brilliant and very different from that found in metallic fish. Chen (1934) mentions that blue spots mingled with red, yellow, black, and white are found on the body of calico (nacreous) fish.

Chen did not give particulars of how the colours are produced in nacreous fish but in metallic varieties he described the colours as being produced by melanophores, "orange xanthophores", and reflecting tissue.

Matsui (1934), whose illustrations show various combinations of orange, blue, black, and a dull green, did not investigate chromatophores but only the colours produced.

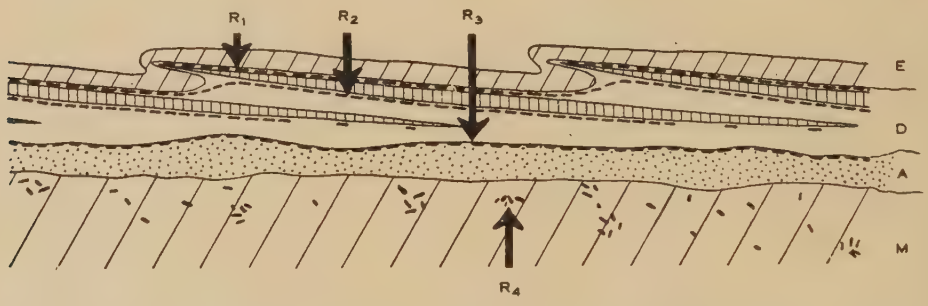

Fig. 3.—Horizontal section through scales and surrounding tissues, showing distribution of chromatophores. *E*, epidermis; *D*, dermis; *A*, adipose tissue; *M*, myotomes; vertical hatching — scales; R_1, first region of chromatophores; R_2, second region of chromatophores; R_3, third region of chromatophores; R_4, fourth region of chromatophores.

Pereira (1937), in a popular account of the goldfish varieties of China, stated that not more than three colour pigments (colours?), namely black, orange, and blue, can be present in any goldfish. In a later paragraph he says that red in the correct sense is very uncommon but that in Kwangtung, the Ying goldfish can claim this distinction—the red has the depth of dilute ox-blood and, as this variety has all its fins white or creamy, the red colour is all the more striking.

Although the colours and their arrangements vary considerably in fish of the nacreous group, it is apparent from external examination that they are produced from the basic colours black, a smoky blue (smoke), blue, orange, yellow, blood-red, and silver arranged singly or in combinations.

Figure 3 shows the possible dispositions of chromatophores affecting the colours of *C. auratus* in the body of the fish. All occur beneath the epidermis. The first position in which they may be found (Fig. 3, R_1) is just above the scales. The second region (R_2) occurs just beneath the scales and is continuous with the first region of the next anterior scale. The third region (R_3) is beneath the dermis and immediately above a layer of adipose tissue, while the fourth region (R_4) is in the myotomes. Melanophores may occur in all regions but in none of the specimens examined were xanthophores or erythrophores found outside the first and second regions.

Fig. 4.—Melanophore from a nacreous fish.

Melanophores are normally much branched, or reticulate (Parker 1948), but vary considerably in form from a simple structure with a few branching arms to those of very great complexity as shown in Figure 4. Their colours vary from a jet black through varying tints of brownish grey to almost white. Melanophores in an adult fish of the nacreous group are almost invariably larger than those found in the wild-type coloured fish of the metallic group. The difference in size may be seen by comparing

Figures 4 and 6, each of which is from a fish 45 mm. long. These particular melanophores were removed from the lateral line region immediately beneath the anterior margin of the dorsal fin.

Melanophores in the first region (Fig. 3) appear their natural colour when viewed externally. When they are densely crowded they give a black appearance to the fish but when they are scattered sufficiently to

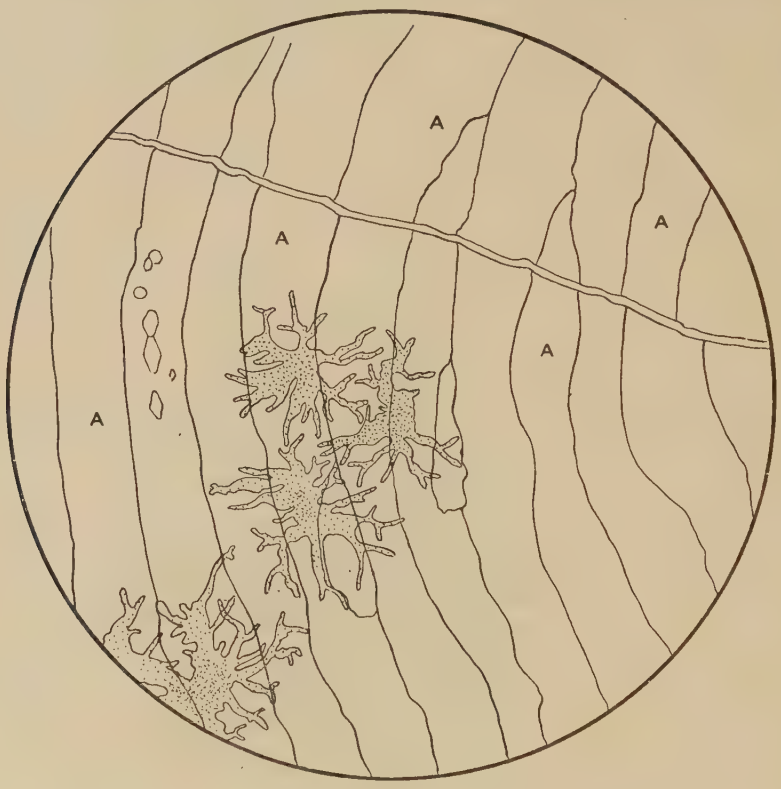

Fig. 5.—Erythrophores from a nacreous fish. *A*, erythrophores densely crowded.

allow underlying tissue without chromatophores to be seen the fish appears grey. When they are not densely crowded it would appear that there is a tendency for them to occur in scale patterns although they do not invariably do so.

Melanophores in the second region appear smoky blue (smoke). The deeper they are beneath the surface of the epidermis the bluer they appear. Most of them in this region occur below the position of the reflecting tissue layer (L_1).

Melanophores in the third and fourth regions, when not masked by superficial chromatophores or reflecting tissue, appear as a brilliant blue. This colour is very different from the dull, smoky blue found in Chinese

scaled (metallic) varieties as described by Chen (1925). In the third region they tend to occur above the reflecting tissue (L_2).

Chromatophores containing yellow or orange pigments are smaller in size and simpler in their branchings than melanophores. They are larger in fish of the nacreous group than in greyish olive fish of the metallic group of similar size, as may be seen by comparing Figures 5 and 6. As with melanophores, the intensity of the colour varies and

Fig. 6.—Chromatophores from a olive-grey wild-type fish. Melanophores natural colour, xanthophores and erythrophores white.

they may be almost white. In fish of the nacreous group and in specimens of the metallic group that are called gold (orange), the pigments are much more intense in colour than those found in the greyish olive fish of the metallic group. When the pigments occur as light tints (dilutions of a standard colour), it is almost impossible to distinguish between the orange and yellow pigments. Some chromatophores are a yellowish orange as might occur if both the orange and yellow pigments were present together, or if one pigment was being developed from the other. Some fish of the nacreous group possess both kinds of chromatophores so that they have yellow as well as orange-coloured patches on their bodies while others possess only one kind and have either orange or yellow patches.

Because of their relatively pale colours xanthophores and erythrophores are difficult to observe. Goodrich and Anderson (1939) mentioned that it is very difficult to distinguish and identify individual cells. When they occur as isolated units of colour or when they are situated on the edge of a dense concentration, it is possible to observe their shape. If a fish is decapitated and a scale and the surrounding tissue are removed and examined under a microscope immediately, their stellate form may be seen. The pigment, however, soon becomes concentrated into a small, circular patch. It is with pigment in this concentrated position that Chen illustrates xanthophores. When damaged, their contents flow out of the cells and may form one or more globules.

The yellow and orange pigments are carotenoids. They turn purple in the presence of iodine in potassium iodide, decolourize when treated with potassium dichromate, and turn an intense blue before decolourizing when treated with concentrated sulphuric acid (Lison 1936).

The position of xanthophores and erythrophores in the first and second regions does not affect their apparent colours to any appreciable extent as does that of melanophores.

Haemoglobin in the blood corpuscles may be responsible for some of the colour in nacreous fish. The blood-red colour of some opercula is caused by blood in the gill filaments seen through the tissues and transparent bones. In the absence of chromatophores and reflecting tissue blood within the body of a fish gives it a pale pink appearance.

Table 1 shows the factors responsible for colours in goldfish. All of them are present in the greyish olive wild-type fish (as already stated by Chen), with the possible exception of erythrophores, but only four of them are actually responsible for the greyish olive colour.

The intensity of the colours depends on the abundance of chromatophores and also on the concentration of the pigments within them. Besides the colours mentioned in the table, it is possible for others to occur, produced by combinations of those listed.

IV. Examples of the Nacreous Group

The heterozygous fish (nacreous group) vary considerably in colour and reflecting tissue, as described by Chen (1925, 1928, 1934) and Matsui (1933, 1934), but, although they examined a large number of fish, the following descriptions show that their definitions of the group are incomplete.

Specimen 1 (Plate 1) is a pink-coloured fish. Superficially it appears to belong to Chen's transparent class. Melanophores are absent from the body but there is one small black streak near the anterior margin of the dorsal fin and another much smaller one at the posterior margin. Xanthophores are restricted to two small patches at the base of the caudal fin where it joins the peduncle. The scales are transparent (lack reflecting

TABLE 1

FACTORS RESPONSIBLE FOR COLOUR IN THE GOLDFISH

Colour	Melanophores Regions				Erythrophores Regions		Xanthophores Regions		Reflecting Tissue Layers		Blood
	1	2	3	4	1	2	1	2	1	2	
Metallic black	+								+		
Metallic orange					+				+		
Metallic yellow							+		+		
Metallic silver									+		
Pearl black	+									+	
Pearl smoke		+								+	
Pearl orange					+ and/or +					+	
Pearl yellow							+ and/or +			+	
Pearl blue			+ and/or +							+	
Pearl silver										+	
Matt black	+										
Matt smoke		+									
Matt blue			+ and/or +								
Matt orange					+ and/or +						
Matt yellow							+ and/or +				
Matt pink											+

tissue beneath them) with the exception of two on the right side and one on the left. Some reflecting tissue is present in the right operculum and a small amount is also present in the pupil of the right eye. Reflecting tissue in layer 2 occupies about one-quarter of the whole surface of the fish. The author has seen several specimens similar to this one.

Specimen 2 (Plate 1) is mottled. The general surface of the body appears lilac and is stippled with very small black dots each consisting of from one to five melanophores. These groups of melanophores are closer together in the dorsal region, where they tend to occur in scale patterns, than in the ventral region. Small patches of orange also occur on the body. All the scales appear transparent, while there is no reflecting tissue in the head. The second layer of reflecting tissue occupies about three-quarters of the whole surface. Goldfish fanciers are always endeavouring to breed nacreous fish that are "scaleless" (the scales are not backed by reflecting tissue) and possess "soft gill plates" (the opercula lack reflecting tissue). Fish conforming to these requirements, like specimen 2, may be seen at aquarists' shows but they are not common.

TABLE 2

THE RESULTS OF MATING KNOWN NACREOUS FISH WITH SPECIMENS 1-6

Parent	Offspring	
	Metallic	Non-Metallic
Specimen 1	113	299
Specimen 2	89	261
Specimen 3	65	182
Specimen 4	94	293
Specimen 5	102	327

Specimen 3 (Plate 1) might at first glance be mistaken for a common goldfish as its body is a uniform intense orange, but the orange only occurs in patches on the fins. Parts of the fins lack pigment. Most of the scales, however, appear transparent. The second layer of reflecting tissue occupies about one-half of the whole surface.

Specimen 4 (Plate 1) is a uniform intense yellow without a trace of any other hue. Most of the scales appear transparent. The second layer of reflecting tissue occupies about three-quarters of the whole surface.

Specimen 5 (Plate 1) is a blue fish with some black and smoke-coloured markings. The intensity of the blue varies in different parts of the body. Most of the scales appear transparent. The second layer of reflecting tissue occupies about seven-eighths of the whole surface.

Fish containing only one apparent pigment, like specimens 3, 4, and 5, are uncommon. This is probably due to the fact that fanciers consider a well-mottled fish to be the ideal and eliminate the others.

Each of the five specimens was mated to fish known to belong to the nacreous group. Table 2 shows the results of the matings. The offspring were counted when they were approximately 20 mm. long. At this stage the metallic fish may be distinguished easily although it is not always possible to distinguish between the other groups.

The table shows that all the specimens belong to the nacreous group as the number of metallic offspring from each mating is approximately one-third of the number of non-metallic ones (nacreous and matt).

V. Discussion

In the official descriptions of fancy goldfish published by various aquarists' societies, red is mentioned as a desirable colour for nacreous fish. Chen (1934) and Goodrich (1935) also mention that red is found but neither describe a red chromatophore nor say how any other pigment might produce a red effect. The author has examined a very large number of fish over a period of 15 years but has not found one that was red in any part of the body except for the blood-red due to haemoglobin. The red described by fanciers is much nearer to a standard orange than to a red when compared with Ostwald standard colours.

If the orange pigment is very concentrated and not mixed with the yellow pigment it appears very intense in colour. When the intense orange colour is not surrounded by other chromatophores (i.e. the surrounding colour is a very pale blood-red tint) it appears redder than it really is. The modification of one colour by another is well known to artists. In order to ascertain if orange could be made to appear red, pieces of paper were painted black, yellow, and a blood-red tint as found in nacreous fish. On these three different backgrounds spots of orange were superimposed. The spots on the black and yellow backgrounds appeared orange although there was a slight difference between the two sets. With the blood-red tinted background, however, the orange spots appeared red. The red colour in the specimens examined was an orange although in some cases it appeared to be red.

The difference between an erythrophore and a xanthophore depends solely on the colour of the pigment within the cell. If it is yellow the cell is a xanthophore while if it is "reddish" the cell is called an erythrophore (Parker 1948). The pigment in the cells described by Chen is an orange which sometimes has been reported as red. The cells containing this orange pigment should, therefore, be classed as erythrophores. Although yellow has been reported when describing the colour of fish (Chen 1934; Goodrich 1935), xanthophores containing a yellow pigment are described here for the first time.

Previous workers have suggested that one difference between nacreous and matt fish is that the former are mottled while the latter lack pigment over most of the surface. Matsui (1934) showed that nacreous (mosaic transparent) fish may be piebald or self orange. The present

paper shows that a specimen may lack pigment over all of the body, while only one pigment (black, orange, or yellow) is present in some specimens. Although the matt (transparent) fish described by Chen lack pigment over most of the body, Matsui describes specimens that are piebald (pale orange and pink) and others mottled with pale orange and pale blue. The author has matt specimens that are a very intense orange and others with colours and patterns equal in range to those found in nacreous specimens.

Matsui's description of the heterozygous fish includes specimens with metallic and transparent scales arranged as a mosaic. Specimen 2, however, is a heterozygous (nacreous) fish but does not possess any metallic scales.

The differences between the three groups, with regard to the amount of reflecting tissue, are determined by one pair of alleles. Although the colour blue and the pearl and matt effects do depend on the absence or reduction of the amount of reflecting tissue, the actual pigmentation of nacreous fish is obviously controlled by genes other than those responsible for the amount of the reflecting tissue — as already stated by Matsui. As the essential differences between the groups depend only on the amount of reflecting tissue present, the amount and arrangement of pigmentation must not be used as criteria.

A definition of the nacreous (mottled) group, therefore, is: one that is intermediate between the metallic and matt groups with regard to the amount of reflecting tissue. In the first layer, which occurs just beneath the scales and gives them a metallic appearance, the tissue is only present beneath some scales and may be entirely absent from this layer. In the second layer, where it has a mother-of-pearl (pearl) appearance when not masked by overlying structures, the tissue typically occupies about two-thirds of the whole surface although the amount is subject to considerable variation.

VI. Acknowledgments

The author wishes to express his appreciation of the help given to him by Professor A. Graham, Birkbeck College, University of London; members of the Goldfish Society of Great Britain; Mr. A. D. Butcher, Director of Fisheries and Game, Victoria; Mrs. K. Cooke, and Mr. D. Falconer.

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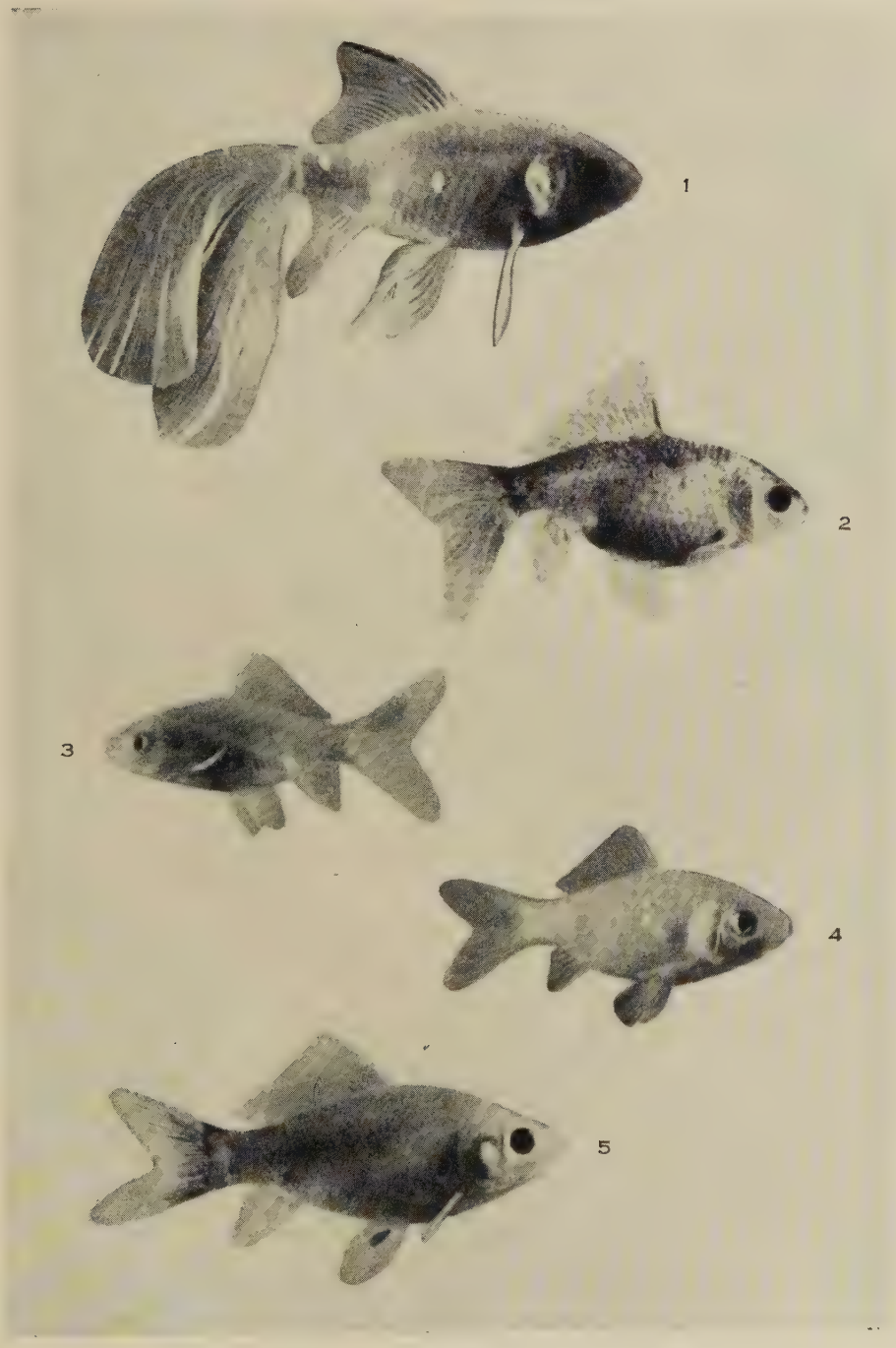
NACREOUS (MOTTLED) GROUP OF THE GOLDFISH



Uncommon examples of nacreous (mottled) goldfish. 1, Pale pink colour; 2, no metallic scales; 3, self orange colour; 4, self yellow colour; 5, black, smoke, and blue colours. For detailed descriptions see text.

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THE EARLY ESTIMATION OF PERCENTAGE FERTILIZATION IN TROUT OVA

By R. J. Affleck*

(*Manuscript received April 8, 1952*)

Summary

Untreated, infertile trout ova may be readily distinguished from untreated, live, fertile ones after 24 hours. After examination the ova may be returned to the hatchery trays. By noting the number of infertile ova in a sample it is possible to estimate the percentage fertilization.

I. Introduction

The use of glacial acetic acid to aid in determining whether ova have been fertilized was first described by Rutter (1902). He stated that a few minutes after they have been placed in dilute (5-10 per cent.) acetic acid the embryos turn white.

Morton (1948) used glacial acetic acid when determining the percentage fertilization of trout ova. Dead ova are cleared by the acid so that the stage of development at which the ova died may be determined. By noting the number of infertile ova in a sample Morton was able to estimate the percentage fertilization. He applied the test to 10-day-old rainbow trout ova in water at 46°F.

II. Fertile and Infertile Ova

Ignoring oil globules, which are very conspicuous, a trout ovum from a rainbow trout (*Salmo gairdnerii* Richardson) 24 hours after fertilization appears as shown in Plate 1, Figure 1. The blastoderm, which is raised above the general surface of the yolk, has an irregular outline as it is composed of a number of blastomeres. An infertile ovum of the same age is very similar in appearance but as cleavage has not taken place the original blastodisc has a regular outline (Plate 1, Fig. 2.). The blastodisc is comparatively opaque.

If a 24-hour fertile ovum and an infertile one of the same age are placed in glacial acetic acid, both the blastoderm of the one and the blastodisc of the other will turn white. Rutter (1902), working with quinnat salmon, stated, "the embryo can be distinguished in this manner within 15 hours after the ovum has been fertilized". With rainbow trout ova treated with acid, however, the author was unable to distinguish between treated fertile and infertile ova by a superficial examination but by using ×20 magnification the blastomeres of the fertile ova could be seen. It is possible to distinguish between fertile and infertile ova that have not been treated with acid as the blastoderm of the former is translucent while the blastodisc of the latter is opaque.

* Fisheries and Game Department of Victoria, Melbourne.

ESTIMATION OF FERTILIZATION IN TROUT OVA

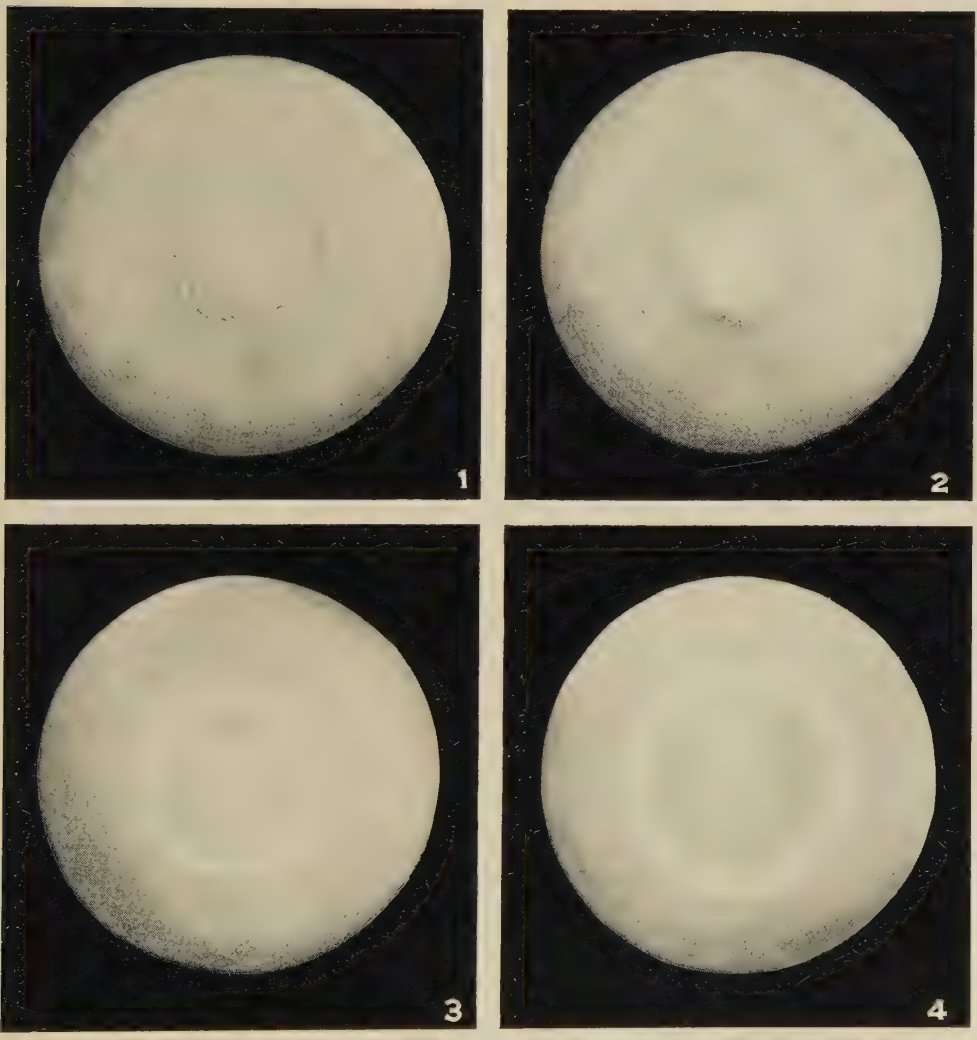

Fig. 1.—Trout ovum 24 hours after fertilization. Outline of blastoderm exaggerated.
Fig. 2.—Infertile ovum 24 hours after stripping.
Fig. 3.—Four-day fertile ovum.
Fig. 4.—Six-day fertile ovum.

Two-day fertile ova cannot be distinguished easily from infertile ova of the same age after treatment with glacial acetic acid. The blastomeres of the former are small and not readily distinguished so that the blastoderm is very similar to the blastodisc. Again, however, the fertile ovum that has not been treated with acid may readily be distinguished from an infertile one as the blastoderm of the former is translucent while the blastodisc of the latter is opaque.

From the fourth day onwards glacial acetic acid may be used to accentuate the appearance of any growth that has taken place within a fertile ovum. As the blastodisc of an infertile ovum has begun to disintegrate by this period, in a mixed batch, the fertile ova may be distinguished comparatively easily after treatment with acid. However, untreated 4-day fertile ova may be recognized as shown in Plate 1, Figure 3, while at 6 days the germ ring and embryonic shield are plainly visible (Plate 1, Fig. 4).

The acetic acid treatment is useful when examining dead ova because, as already stated (Morton 1948), they are cleared by the acid so that the stage of development at which they died may usually be determined.

These observations were made on the ova of rainbow trout (*Salmo gairdnerii*) in water at 52°F. When examining untreated ova the author used a dip tube, held almost horizontally, to remove them from the hatching trays. The tube was then carried near to a window and held against a dark background when details of the ova could be seen by reflected light. The opaque blastodisc of an unfertile ovum was more easily recognized by transmitted light. After examination the ova were returned to the hatching trays where they continued development.

III. Conclusions

1. Twenty-four hours after stripping, the opaque blastodisc of an infertile trout ovum may be distinguished from the translucent blastoderm of a live fertile ovum.

2. By noting the number of fertile ova in a sample it is possible to estimate the percentage fertilization.

3. After examination the ova may be returned to the hatching trays.

IV. Acknowledgment

The author wishes to express his thanks to Mr. A. D. Butcher, Director of Fisheries and Game, Victoria, for making helpful suggestions.

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ZINC POISONING IN A TROUT HATCHERY

By R. J. Affleck*

(*Manuscript received May* 29, 1952)

Summary

Natural acid waters will dissolve zinc from galvanized-iron pipes. In some acid waters with a very low mineral content 0.01 p.p.m. dissolved zinc is toxic to brown and rainbow trout ova and alevins. All stages in the life history of rainbow trout are more susceptible to zinc poisoning than corresponding stages of brown trout. The lethal concentration normally decreases with the age of the fish, but considerable variations have been recorded amongst ova, alevins, fry, and fingerlings. Survivors from batches of fish subjected to dissolved zinc are less susceptible to further toxic concentrations than are specimens that have not previously been in solutions of zinc. Under certain conditions mortality amongst trout fingerlings, due to zinc poisoning, will occur after they have been in a zinc vessel for 15 min. The effects of zinc poisoning may not be immediately apparent. When removed from zinc-contaminated to relatively zinc-free water trout may appear normal but death may occur within 48 hr.

In well-aerated water, little or no flow is necessary for the development of trout ova, which will develop normally in distilled water.

Aluminium paint does not normally protect an underlying metal from the action of acid water. Zinc is an unsuitable material for use in a hatchery with an unbuffered water supply.

The lethal temperatures for acclimatized brown (*Salmo trutta* L.) and rainbow (*Salmo gairdnerii* Richardson) trout fingerlings in Victoria are 29°-30°C. For adult fish the temperatures are 27°-29°C.

A self-cleaning hatchery inlet screen and a spray jet for circular ponds are described. In hot climates the temperature of water entering a pond through a spray jet is less than that of water entering through a normal radial-arm jet.

I. Introduction

Extremely severe losses of trout ova, alevins, fry, and fingerlings (*Salmo trutta* L. and *S. gairdnerii* Richardson) have been experienced over a period of 6 years at Snobs Creek Hatchery and Research Station owing to zinc dissolved from the galvanized-iron pipes of the water system. Although the work is incomplete, it was felt that in addition to a preliminary note (Affleck 1952*a*), the present data may be of use to authorities contemplating the construction of a hatchery. Over 300 individual experiments were carried out under field conditions as the hatchery is still under construction.

The hatchery is situated in north-eastern Victoria (37° 10'S., 145° 39'E.) and straddles Snobs Creek just above its junction with the Goulburn River.

* Fisheries and Game Department of Victoria, Melbourne.

Snobs Creek is approximately 16 miles long, has a catchment area of approximately 50 sq. miles, is comparatively straight, and falls 2500 ft. Numerous small streams enter the creek above the hatchery site. The catchment area is mainly forest with much undergrowth (Plate 1, Fig. 2) and the sides of the valley are steep. The flow of water in Snobs Creek during the summer (dry season) is normally only slightly less than in winter (wet season).

The typical pH of the creek water is 6.8. During heavy rains large quantities of decaying vegetation are washed into the creek (0.155 g./l. of suspended solids have been recorded) by water flowing down the steep sides of the valley. As the water is unbuffered (Table 1) a small increase in the amount of dissolved carbon dioxide (due to decomposition of vegetation) reduces the pH appreciably. When the rains cease, however, the pH usually returns to normal within 24 hr.

TABLE 1

ANALYSIS (P.P.M.) OF WATER FROM SNOBS CREEK TAKEN DURING THE AUTUMN (PERIOD OF LITTLE RAIN)

Total solids		36
Dissolved solids:		
Calcium*	(Ca^{++})	1.7
Magnesium	(Hg^{++})	1.0
Sodium	(Na^{+})	2.5
Potassium	(K^{+})	0.8
Bicarbonate	(HCO_3^{-})	9.8
Sulphate	(SO_4^{--})	0.6
Chloride	(Cl^{-})	3.2
Nitrate	(NO_3^{-})	0.15
Colloidal matter:		
Silica	(SiO_2)	15.0
Aluminium oxide and iron oxide	(Al_2O_3 and Fe_2O_3)	1.5

* As calcium bicarbonate.

Early rains wash much vegetation into the creek and disturb the residual silt. Later there is comparatively little vegetation in positions near the creek and its bed is clean. Late rains, therefore, have little effect on pH (Fig. 1).

Water to the hatchery passes along an open race from Snobs Creek and then down pipes to hatching houses, circular ponds, etc. Vertical screens of bronze and galvanized iron, both treated with aluminium paint, prevent debris from entering the water systems. Because of the large amount of silt and leaves in the creek, these screens become clogged very quickly, especially after heavy rain. It was noted that although they had been painted recently, the paint had been removed, or could be removed easily, where the metal is in contact with water.

Water to the hatching houses flows from the race through a sedimentation tank and 2-in. galvanized-iron pipes. Inside the houses it flows down 1-in. galvanized-iron pipes to galvanized-iron troughs that had been treated with aluminium paint. Galvanized-iron hatching trays, treated with aluminium paint, are suspended in the troughs.

From the race water flows via concrete pipes and short lengths of galvanized-iron pipes to circular ponds. The radial-arm jets and central overflow pipes of the ponds are of galvanized iron. Central outlet screens are of bronze treated with aluminium paint.

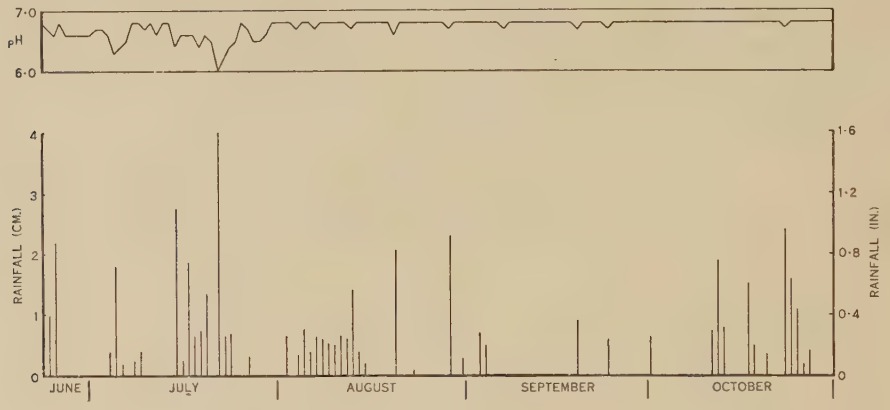

Fig. 1.—Daily rainfall and pH of water in hatchery race during trout hatching season.

II. Preliminary Observations

Ova were stripped into dry enamel bowls and sperms added. They were washed almost immediately after fertilization and then placed on

Table 2

DEVELOPMENT OF TROUT OVA IN WATER THAT HAS PASSED THROUGH GALVANIZED-IRON PIPES AT 4-9°C.

Batch No.	Species	Total Ova	Eyed	Hatched	Eyed (%)	Hatched (%)
1	Brown trout*	115		17		15
2	Brown trout	282	214	20	76	7
3	Brown trout	118	83	17	70	15
4	Rainbow trout	518	441	4	85	1

* Eyed ova.

hatching trays or in artificial redds. One to three days afterwards samples were examined to determine if fertilization had taken place (Affleck 1952*b*). All ova that "turned white" were removed and treated with glacial acetic acid, which clears them and enables the stage of development attained at death to be determined (Rutter 1902).

Tables 2 and 3 show typical results obtained in the hatching houses with four batches of ova. Half of each were placed in water that had passed through a small limestone filter.

TABLE 3

DEVELOPMENT OF TROUT OVA IN WATER THAT HAS PASSED THROUGH GALVANIZED-IRON PIPES AND A SMALL FILTER CONTAINING LIMESTONE

(The batches are as those in Table 2, temperature 4-9°C.)

Batch No.	Species	Total Ova	Eyed	Hatched	Eyed (%)	Hatched (%)
1	Brown trout*	187		45		24
2	Brown trout	87	69	23	79	26
3	Brown trout	180	138	33	70	18
4	Rainbow trout	471	402	10	85	2

* Eyed ova.

The presence of limestone in the water raised the pH as shown in Figure 2. The effect was most marked after heavy rains (compare

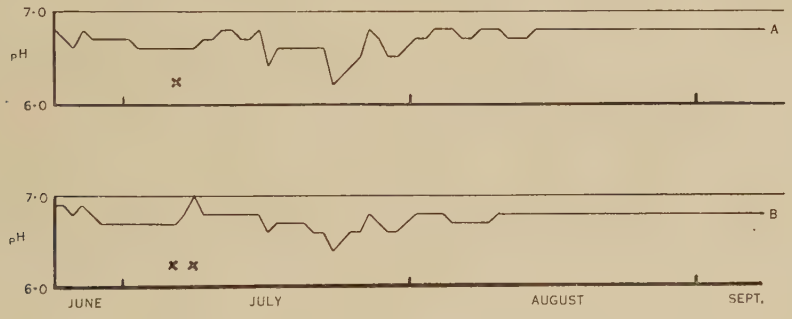

Fig. 2.—pH of water in hatching troughs. *A*, through empty drum. *B*, through drum containing limestone. +, Flow of water stopped.

Figs. 2 and 1). The presence of limestone increased the percentage hatched.

TABLE 4

A COMPARISON BETWEEN THE DEVELOPMENT OF BROWN TROUT OVA IN THE HATCHING HOUSE AND IN A CIRCULAR POND

	Hatching House	Circular Pond
Total eyed ova	31,763	5,000
Alevins after 80 days	3,031	4,122
Survival (%)	9	82

Table 4 shows typical results obtained (from one batch of ova) with eyed ova in a hatching house and in a circular pond. In the pond, which was filled with water to a depth varying from 20 to 40 cm., ova were

buried among stones. No fresh water was added to the pond until high temperatures made it imperative to do so. It was only after the water had been turned on that mortality was apparent in the pond.

These preliminary observations suggested that some toxic substance was present in the running water and that the addition of calcium partially neutralized the effect. Experiments showed that the toxic substance was zinc.

III. Zinc Poisoning of Trout

In the following experiments ova and sperms were obtained from brown or rainbow trout that had been trapped in tributaries of the Goulburn River.

Experiments 1 and 2 show the effects of different environments on ova.

Experiment 1

Fertilized ova from two rainbow trout were thoroughly mixed and distributed as follows:

A.—Galvanized-iron hatching trough treated with aluminium paint; ova on galvanized-iron hatching tray treated with aluminium paint; water from Snobs Creek via galvanized-iron pipes of the hatching house system.

B.—Glass tank 33 by 20 by 41 cm.; distilled water, depth 5 cm.; ova on muslin draped into water; ova 1.2 cm. below surface; bubbles of air introduced via rubber tube from electric pump.

C.—Glass tank as in *B;* still water from Snobs Creek with limestone; ova on muslin; depth of water 25 cm.; ova 1.2 cm. below surface.

D.—Glass tank as in *B*; water from Snobs Creek with limestone; ova on muslin; depth of water 25 cm.; ova 1.2 cm. below surface; bubbles of air introduced via rubber tube from electric pump.

E.—Glass tank as in *B*; running water from Snobs Creek via galvanized-iron pipes; ova on muslin; depth of water 41 cm.; ova 5 cm. below surface.

F.—Glass tank as in *B*; running water from Snobs Creek via rubber tube; ova on muslin; depth of water 41 cm.; ova 5 cm. below surface. Ova became covered with silt very quickly and at conclusion of experiment were buried by 1 cm. of silt.

G.—Galvanized-iron tank 60 by 30 by 20 cm. coated with aluminium paint; running water from tributary of Snobs Creek via new galvanized-iron pipe; ova on galvanized-iron tray treated with aluminium paint.

H.—Glass tank as in *B*; running water from a tributary of Snobs Creek via rubber pipe; ova on muslin; depth of water 41 cm.; ova 5 cm. below surface. Ova became covered with silt very quickly and at conclusion of experiment were buried by 1 cm. of silt.

I.—Galvanized-iron trough as in *A*; running water from Acheron River via galvanized-iron pipes; ova on galvanized iron as in *A*. The Acheron River is situated 15 miles west of Snobs Creek.

Table 5 gives details of development and some analyses for zinc.

TABLE 5

EFFECTS OF DIFFERENT ENVIRONMENTS ON THE DEVELOPMENT OF RAINBOW TROUT OVA AT 4-9°C.

pH of water from Snobs Creek during experiment 6.7-6.8

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
Total ova	382	28	33	27	31	217	281	170	1,000
Infertile	25	1	2	2	3	13	11	15	81
Died before eyed stage	279	0	0	2	0	11	270*	21	299
Died at eyed stage	78	2	5	0	19	193	0	134	610
Hatched	0	25	26	23	9	0	0	0	0
Fertile (%)	94	96	94	92	91	94	95	91	92
Eyed (%)	20	96	94	85	90	89	0	80	61
Hatched (%)	0	89	79	85	29	0	0	0	0
Zn (p.p.m.)	0.04	0.02	0.003	0.003					

* Died within 24 hr.

Experiment 2

Fertilized ova from two rainbow trout were thoroughly mixed and distributed as follows:

A.—Galvanized-iron hatching trough treated with aluminium paint; ova on galvanized-iron tray treated with aluminium paint; running water from Snobs Creek via galvanized-iron pipes of the hatching house system; flow 18 l./min.

TABLE 6

EFFECTS OF DIFFERENT ENVIRONMENTS ON THE DEVELOPMENT OF RAINBOW TROUT OVA AT 4-9°C.

	A	*B*	*C*	*D*
Total ova	371	224	51	75
Infertile	26	26	2	9
Died before eyed stage	153	89	49*	0
Died at eyed stage	192	97	0	5
Hatched	0	12	0	61
Fertile (%)	93	89	98	88
Eyed (%)	51	49	0	88
Hatched (%)	0	5	0	81

* Died within 24 hr.

B.—As in *A*, but flow 36 l./min.

C.—Trough and tray as in *A*; water via new galvanized-iron pipe 15 ft. long, 2 in. diameter; flow 18 l./min.

D.—Glass tank 33 by 20 by 41 cm.; water from Snobs Creek; ova on muslin; bubbles of air introduced via rubber tube from electric pump; depth of water 5 cm.; ova 1.5 cm. below surface.

Table 6 gives details of development.

Results from experiments 1 and 2 show that:

(1) Mortality was great amongst ova in contact with galvanized iron treated with aluminium paint, in water that had passed through galvanized-iron pipes, and buried in silt;

TABLE 7

MORTALITY OF A BATCH OF BROWN TROUT OVA SUBJECTED TO DISSOLVED ZINC (*A*, 2968 OVA) AND CONTROL (*C*, 52 OVA) AT 7-13°C.

Day	Daily Pickings		Totals		Day	Daily Pickings		Totals	
	A	*C*	*A*	*C*		*A*	*C*	*A*	*C*
1	3	0	3	0	31	18	0	218	3
2	2	0	5	0	32	3	0	221	3
5	13	0	18	0	33	10	0	231	3
8	9	0	27	0	36	6	0	237	3
13	5	0	32	0	38	10	0	247	3
14	1	0	33	0	41	5	1	252	4
15	7	0	40	0	42	10	0	262	4
16	14	0	54	0	43	12	0	274	4
17	65	2	119	2	53	2	0	276	4
18	18	0	137	2	57	2	0	278	4
22	26	0	163	2	59	23	0	301	4
23	15	0	178	2	64	13	0	314	4
24	3	0	181	2	65	8	0	322	4
25	7	0	188	2	66	4	0	326	4
28	11	0	199	2	68	0	0*	326	4
30	1	1	200	3	71	*	1		5
					77	103	1	429	6

	A	*C*
Total ova	2,968	52
Infertile	89	4
Died before eyed stage	117	2
Died at eyed stage	223	0
Died at alevin stage (6 days)	714	0
Fertile (%)	97	92
Eyed (%)	93	88
Hatched (%)	85	88
Survival 6 days after hatching (%)	62	88

* Hatching commenced. After day 71 is was impossible to determine exactly when ova died in group *A*.

(2) When the flow of water through galvanized-iron pipes was increased, some ova hatched although the percentage was small;

(3) Ova developed in aerated distilled water;

(4) Ova developed in aerated creek water;
(5) Ova developed in still creek water; and
(6) In unbuffered, running water the toxic concentration of dissolved zinc is very small.

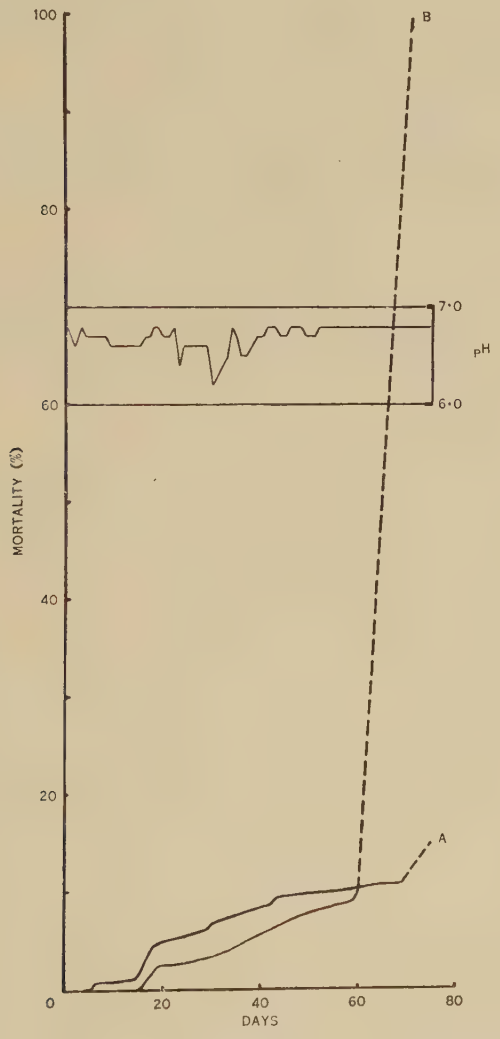

Fig. 3.—Percentage mortality of two batches of brown trout ova subjected to dissolved zinc, and pH of water in which ova developed. At the end of the periods it was impossible to determine exactly when ova died. Actual daily losses are shown in Tables 7 and 8.

Experiments 3 and 4 show the progressive effect of dissolved zinc on mortality of ova, as experienced at the hatchery.

Experiment 3

Fertilized ova from a brown trout were distributed as follows:

A.—Galvanized-iron hatching trough treated with aluminium paint; ova on galvanized-iron tray treated with aluminium paint; running water from Snobs Creek via galvanized-iron pipes of hatching house system.

C.—Enamel bowl; ova on muslin draped into water; running water from Snobs Creek via rubber tube.

Details of development are shown in Table 7.

In group *A* mortality amongst alevins was increasing rapidly when they were removed from the trough. The percentage mortality and pH of the water are shown graphically in Figure 3.

Experiment 4

Fertilized ova from a brown trout were distributed as follows:

B.—Trough, tray, and water similar to experiment 3*A*.

D.—Enamel bowl, muslin, and water similar to experiment 3*C*.

Details of development are shown in Table 8.

TABLE 8

MORTALITY OF A BATCH OF BROWN TROUT OVA SUBJECTED TO DISSOLVED ZINC (*B*, 689 OVA) AND CONTROL (*D*, 47 OVA) AT 8-13°C.

Day	Daily Pickings		Totals		Day	Daily Pickings		Totals	
	B	*D*	*B*	*D*		*B*	*D*	*B*	*D*
16	1	0	1	0	45	2	0	48	1
17	5	1	6	1	49	2	0	50	1
19	11	0	17	1	51	6	0	56	1
26	1	0	18	1	57	7	0	63	1
27	4	0	22	1	60	14	0	77	1
34	4	0	26	1	66		0*		1
					71	612	1	689	2

	B	*D*
Total ova	689	47
Infertile	34	1
Died before eyed stage	21	1
Died at eyed stage	634	0
Fertile (%)	95	98
Eyed (%)	92	96
Hatched (%)	0	96

* Hatching commenced. After day 60 it was impossible to determine exactly when the ova in group *B* died.

The percentage mortality and pH of the water are shown graphically in Figure 3.

A decrease in pH, which would result in zinc being dissolved faster than normal, did not appear to have any immediate effect on mortality in either *A* or *B*.

Experiment 5

Experiment 5 shows the effects of galvanized iron, galvanized iron treated with aluminium paint, and aluminium paint on the development of ova. Fertilized ova from a rainbow trout were distributed as follows:

A.—Glass tank; ova resting on galvanized-iron gauze; running water from Snobs Creek via rubber tube.

B.—As in *A*, but ova resting on galvanized-iron gauze treated with aluminium paint.

C.—As in *A*, but ova resting on muslin draped in water.

D.—As in *C*, but ova resting on muslin painted with aluminium paint.

Details of development are shown in Table 9.

TABLE 9

EFFECTS OF GALVANIZED IRON, GALVANIZED IRON TREATED WITH ALUMINIUM PAINT, AND ALUMINIUM PAINT ON THE DEVELOPMENT OF RAINBOW TROUT OVA AT 8-12°C.

	A	*B*	*C*	*D*
Total ova	100	114	108	112
Infertile	2	0	4	0
Died before eyed stage	98	23	1	0
Died at eyed stage	0	71	0	2
Hatched	0	11	103	110
Fertile (%)	98	100	96	100
Eyed (%)	0	72	95	100
Hatched (%)	0	10	95	98

Results from experiment 5 show that:

(1) Galvanized iron in water from Snobs Creek is injurious to rainbow trout ova;

(2) Aluminium paint in water from Snobs Creek is not injurious to rainbow trout ova; and

(3) Aluminium paint used at the hatchery only partially protects galvanized iron from the action of the acid water.

Experiment 6

Experiment 6 shows the effect of a very small amount of dissolved zinc on rainbow trout alevins. Rainbow trout eyed ova from Tasmania were placed on muslin draped into a concrete trough. Running water from Snobs Creek flowed into the tank through a rubber hose. No ova died. After the alevins had hatched some were distributed as follows:

A.—Concrete circular pond 4.5 m. diameter; running water from Snobs Creek via concrete pipes and short length of old galvanized-iron pipe; flow 36 l./min.

B.—Concrete trough 100 by 25 by 25 cm.; running water from Snobs Creek via rubber hose; flow 4½ l./min.

During the experiment the pH of water in the creek was unchanged.

Details of development are shown in Table 10.

Results from experiment 6 show that a very small concentration of zinc is toxic to rainbow trout alevins in the water from Snobs Creek. Mortality had not ceased at the conclusion of the experiment.

TABLE 10

EFFECT OF DISSOLVED ZINC ON RAINBOW TROUT ALEVINS (*A*) AND CONTROLS (*B*) AT 8-12°C.

	A	*B*
Total alevins	626	49
Alive after 28 days	286	48
Survival after 28 days (%)	46	98
Zn (p.p.m.)	0.01	0.003

Experiment 7

Experiment 7 compares the effect of dissolved zinc on rainbow and brown trout fingerlings. Specimens 6 cm. long (survivors from ova previously exposed to zinc-contaminated water) were kept under identical conditions for 5 weeks and then transferred as follows:

A.—Large metal tank with running water supplied through galvanized-iron pipes.

B.—Concrete pond with running water supplied through "Fibrolite" (asbestos cement) pipes.

Mortality is recorded in Table 11.

TABLE 11

COMPARISON OF THE EFFECTS OF ZINC IN SOLUTION ON RAINBOW AND BROWN TROUT FINGERLINGS (*A*) AND CONTROLS (*B*) AT 9-12°C.

	A		*B*	
	Rainbow	Brown	Rainbow	Brown
Total fingerlings	18	18	27	8
Dead after 12 hr.	3	0	0	0
Dead after 18 hr.	14	0	0	0
Dead after 24 hr.	18	0	0	0
Alive after 20 days	0	18	27	8
Zn (p.p.m.)	0.13		0.003	

The results show that rainbow trout fingerlings are much more susceptible than brown trout fingerlings to the effects of small concentrations of dissolved zinc.

Experiment 8

Experiment 8 shows that some metal containers are not suitable for transporting trout when unbuffered water is used. Rainbow and brown trout fingerlings (5-7.5 cm.) were placed in three containers and then transported in a car for 4 hr.

A.—Galvanized-iron fish can treated with aluminium paint; volume of water 22 l.; area of can in contact with water 2000 sq. cm.

B.—As in *A*, but can painted inside with bituminous paint.

C.—Enamelled pail; volume of water 4 l.; area of pail in contact with water 350 sq. cm.

Owing to vibration, water in the containers was well aerated during the journey and pH only decreased from 6.8 to 6.6 At the end of the journey all fingerlings appeared normal. Fish from each container were emptied into separate ponds and observed for 72 hr. Table 12 shows survival of fingerlings after being transferred to ponds with water not contaminated with zinc.

TABLE 12

AFTER EFFECTS ON TROUT FINGERLINGS OF TRANSPORT IN DIFFERENT CONTAINERS FOR 4 HR.

Time (hr.)	Number of Fingerlings Alive					
	A		*B*		*C*	
	Rainbow	Brown	Rainbow	Brown	Rainbow	Brown
0	50	50	50	50	10	10
18	38	50	50	50	10	10
24	34	50	50	50	10	10
36	31	50	50	50	10	10
48	28	50	50	50	10	10
72	28	50	50	50	10	10
Survival (%)	56	100	100	100	100	100

The results show that:

(1) Enamelled iron has no adverse effect on fingerlings;

(2) Bituminous paint has no adverse effect on fingerlings;

(3) Although fingerlings from the galvanized-iron can treated with aluminium paint appeared normal when transferred to the pond, many died later. Before death occurred they exhibited signs associated with zinc poisoning (see after Experiment 11); and

(4) Brown trout fingerlings appeared to be normal at the conclusion of the experiment.

Experiment 9

Experiment 9 shows that the toxic effect may be neutralized and that some batches of fishes are more susceptible than others to zinc

poisoning. Rainbow and brown trout fingerlings (5-7.5 cm.) were placed in five containers and transported in a car for 4 hr.

A.—Galvanized-iron can treated with aluminium paint and then with bituminous paint; fingerlings survivors previously exposed to zinc-contaminated water; pH 6.6-6.8; temp. 15°-19°C.

B.—Galvanized-iron can treated with aluminium paint; fingerlings as in *A*; pH 6.6-6.8; temp. 15°-19°C.

C.—Galvanized-iron can as in *B*; fingerlings survivors from experiment 8*A* (i.e. recent survivors from zinc-contaminated water); pH 6.6-6.8; temp. 15°-19°C.

D.—Galvanized-iron can as in *B*; fingerlings not previously exposed to zinc-contaminated water; pH 6.6-6.8; temp. 15°-19°C.

E.—Galvanized-iron can as in *B*; powdered limestone added to water; fingerlings as in *A* above; pH 7.2-7.3; temp. 15°-19°C.

TABLE 13

AFTER EFFECTS ON TROUT FINGERLINGS OF TRANSPORT IN DIFFERENT CONTAINERS FOR 4 HR. *R*, RAINBOW; *B*, BROWN

Time (hr.)	Number of Fingerlings Alive									
	A		*B*		*C*		*D*		*E*	
	R	*B*	*R*	*B*	*R*	*B*	*R*	*B*	*R*	*B*
0	20	24	19	24	20	24	20	24	20	24
12	20	24	16	24	20	24	17	24	20	24
18	20	24	14	24	20	24	11	24	20	24
24	20	24	13	24	20	24	3	24	20	24
48	20	24	13	24	20	24	3	24	20	24
72	20	24	13	24	20	24	3	24	20	24
Survival (%)	100	100	68	100	100	100	15	100	100	100

At the end of the journey all fingerlings appeared normal. Fish from each container were emptied into separate ponds and observed for 72 hr. Table 13 shows survival of fingerlings after being transferred to ponds with water not contaminated by zinc.

The results show that:

(1) The addition of limestone to the water raises the pH so that, for the period of the experiment, the amount of zinc dissolved by the water was below the toxic limit; and

(2) The survivors from batches of fingerlings previously exposed to toxic concentrations of dissolved zinc (*B* and *C*) are not as susceptible to toxic concentrations as fingerlings not previously exposed to dissolved zinc (*D*).

Experiment 10

Experiment 10 shows that mortality amongst brown trout fingerlings may occur if they are carried in cans with an unprotected zinc surface containing unbuffered water. Brown trout fingerlings (7-10 cm.) were placed in two containers and transported in a car for 4 hr.

A.—Galvanized-iron can treated with aluminium paint except for an area inside approx. 100 sq. cm.; temp. 16°-19°C.

B.—Can as in *A*, but treated with bituminous paint; temp. 16°-19°C. After the journey the fish were transferred to ponds and observed as in previous experiments. Table 14 shows survival of fingerlings in ponds.

TABLE 14

AFTER EFFECTS ON BROWN TROUT FINGERLINGS OF TRANSPORT IN GALVANIZED-IRON CAN FOR 4 HR. (*A*), AND CONTROLS (*B*)

Time (hr.)	Number of Fingerlings Alive	
	A	*B*
0	23	24
18	21	24
24	17	24
40	15	24
48	14	24
72	14	24
Survival (%)	58	100

When the zinc coating in these fish cans is exposed to acid water the concentration of dissolved zinc may be lethal, even to brown trout fingerlings, after 4 hr.

Experiment 11

After trout fingerlings had been moved from one part of the hatchery to another in galvanized-iron tubs, it was noticed that some fingerlings subsequently exhibited signs of zinc poisoning and died within 48 hr. Experiment 11 shows the effect of placing fingerlings in a galvanized-iron tub containing unbuffered water for a short period.

Fingerlings from one pond were placed as follows:

A.—Enamelled pail; 7 l. of water from Snobs Creek; 200 rainbow trout fingerlings (6-9 cm.).

B.—Galvanized-iron pail similar in size and shape to that in *A*; 7 l. of water from Snobs Creek; 200 rainbow trout fingerlings as above.

After 15 min., when the pH in each pail had decreased from 6.8 to 6.1, the two batches of fingerlings were transferred to separate ponds containing water not contaminated by zinc and observed for 72 hr. Table 15 shows survival of fingerlings in the ponds.

It would appear that the rapid decrease in pH resulted in zinc being dissolved from the galvanized-iron pail and a toxic solution produced comparatively quickly. It was not until 6 hr. after being released into the pond that the first fingerling began to exhibit signs of zinc poisoning.

The following signs of zinc poisoning have been noted:

(1) Whitish, cloudy, opaque substance visible, through chorion, in the perivitelline space of ova during the late eyed stage.

(2) If death occurs just before the normal hatching period the dead embryo may "hatch", usually yolk sac, or head, first.

(3) Alevins and fry are darker in colour than normal specimens.

(4) The equilibrium of alevins, fry, and fingerlings is affected and they tend to swim in spirals.

TABLE 15

AFTER EFFECTS ON RAINBOW TROUT FINGERLINGS FROM REMAINING IN A GALVANIZED-IRON PAIL FOR 15 MIN. (*B*), AND CONTROL (*A*)

Time (hr.)	Number of Fingerlings Alive	
	B	*A*
0	200	200
16	179	200
40	175	200
48	175	200
72	175	200
Survival (%)	87	100

(5) Alevins, fry, and fingerlings swim rapidly for a short period and then sink, apparently exhausted, to the bottom of a tank or pond but later resume normal swimming again. This behaviour may last for 5-6 hr. with the periods of exhaustion becoming longer and longer before death finally occurs.

(6) Alevins, fry, and fingerlings often appear to be partially paralysed on one side.

(7) A coating of mucus is apparent over the gill filaments.

(8) The rate of opercular movements is increased.

IV. Infertile and Dead Ova

Morton (1948) treated dead ova with glacial acetic acid and found that "97% of dead green ova" (not yet eyed) were infertile. This result suggested to him that the normal pickings are mostly infertile ova and that they are more apt to turn white soon after being stripped than after they have been held on hatching trays for some time.

Gray (1932) found that when an egg turns white the loss of transparency occurs after a breakdown of the impermeable property of

the vitelline membrane. He also noted that the stability of the vitelline membrane varies with four factors: the age of the ovum, degree of mechanical disturbance caused by the environment, presence or absence of calcium in the environment, and nature and concentration of the exosmotic reagent used.

The following experiments were conducted to ascertain when infertile ova turn white under conditions at the hatchery, and the relative numbers of fertile and infertile ova that turn white under favourable conditions.

Experiment 12

Ova from a brown trout were stripped into a dry enamel bowl. A sample of these ova was placed on a piece of muslin stretched across a concrete trough containing running water from Snobs Creek supplied through a rubber tube. The ova were examined daily and the muslin agitated occasionally in order to remove deposits of silt. The results are shown in Table 16.

TABLE 16

TIME TAKEN FOR INFERTILE OVA TO TURN WHITE

Total ova	63
Turned white	1 (20)
	3 (35)
Translucent after 60 days	59

Numbers in brackets indicate days that elapsed before ova turned white.

Experiment 13

Ova from rainbow trout stripped into an enamel bowl; sample placed on muslin stretched across concrete trough containing running water.

The ova, which became covered with silt fairly quickly, were left undisturbed for 26 days, when they were washed and examined. After examination those that had not turned white were returned to the trough and, as they did not subsequently become thickly coated with silt, it was possible to record the day on which loss of translucency occurred. The results are shown in Table 17. These infertile ova received more mechanical

TABLE 17

TIME TAKEN FOR INFERTILE OVA TO TURN WHITE

Total ova	210
Turned white	41 (26)
	11 (28)
	1 (32)
	4 (36)
	4 (43)
Translucent after 50 days	149

Numbers in brackets indicate days that elapsed before ova turned white.

disturbance than that usually received by trout ova in a hatching house yet less than one-third of them turned white.

Experiment 14

Female rainbow trout wiped dry with cloth and ova stripped into clean, dry enamel bowl (by this means drops of water were prevented from entering the bowl. In previous stripping operations it was noticed that some seminal fluid tended to flow along the anal fin before entering the bowl); anal fin removed from male, and fish dried before being stripped; bowl containing ova and sperms rocked gently for approximately

TABLE 18
DEVELOPMENT OF A BATCH OF RAINBOW TROUT OVA

Total ova	1,512
Infertile ova turned white	1 (9)
	2 (15)
	1 (22)
	1 (24)
	1 (27)
Infertile ova not turned white	18
Total infertile ova	24
Died before eyed stage	0
Died at eyed stage	5
Total dead fertile ova	5
Hatched	1,483
Fertile (%)	98
Eyed (%)	98
Hatched (%)	98

Numbers in brackets indicate days that elapsed before ova turned white.

15 sec. and then ova washed thoroughly; ova placed on muslin draped into concrete trough containing running water from Snobs Creek via rubber hose. Table 18 gives details of the ova. Scale readings showed the female to be a 3-year-old fish that had not previously spawned.

The flow of water into the trough was approximately 2 l./min. Above the muslin, on which the ova rested, no water movement could be seen. As the ova tended to become coated with silt, they were washed carefully on days 22, 24, and 27 after fertilization. They hatched in the 31-34 days.

Experiment 15

Rainbow trout ova stripped and fertilized as described in experiment 14, and placed in a concrete trough. Scale readings showed the female to be a 2-year-old fish that had not previously spawned. Table 19 gives details of development.

From experiments 12 to 15 the following deductions may be made:

(1) Infertile ova do not necessarily turn white soon after being stripped and there does not appear to be any definite period at which all ova turn white.

(2) Under good conditions both the percentage of infertile ova and the percentage of dead fertile ova should be small.

TABLE 19

THE DEVELOPMENT OF A BATCH OF RAINBOW TROUT OVA

Total ova	482
Infertile ova turned white	2 (7)
	1 (9)
Infertile ova not turned white	3
Total infertile ova	6
Died before eyed stage	4
Died at eyed stage	4
Total dead fertile ova	8
Hatched	468
Fertile (%)	99
Eyed (%)	98
Hatched (%)	97

V. Spray Jets for Circular Ponds

After it had been ascertained that zinc poisoning was responsible for mortality at the hatchery, means were devised to reduce the amount of metal in the hatchery water system to a minimum. A spray jet was

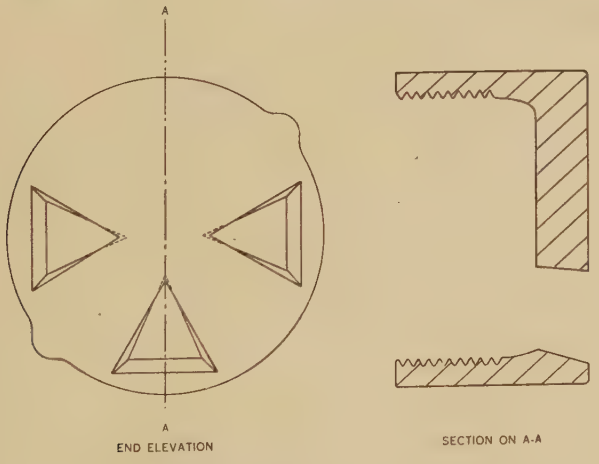

Fig. 4.—Details of spray jet made from standard plug cap.

designed to replace the radial-arm jet, which consisted of a 2-m. length of 3.75 cm. (1½ in.) diameter galvanized-iron pipe with five 0.75 cm. (⅜ in.) diameter holes spaced along its length.

The essential feature of the new jet consists of a standard 3.75 cm. (1½ in.) diameter plug cap in which three triangular splayed holes have been cut (Fig. 4). Figure 5 shows the jet in position. The bend allows the jet of water to be adjusted in a vertical plane. Plate 1, Figure 1,

shows the distribution of water obtained by an experimental jet. In the final model the amount of metal has been still further reduced by incorporating the valve in the vertical pipe.

The main advantages possessed by the spray jet are:

(1) Less material used in construction.

(2) Not easily damaged.

(3) Easily cleaned.

(4) In hot climates the temperature of water entering a pond from a spray jet is less than that from a radial-arm jet (Section VII).

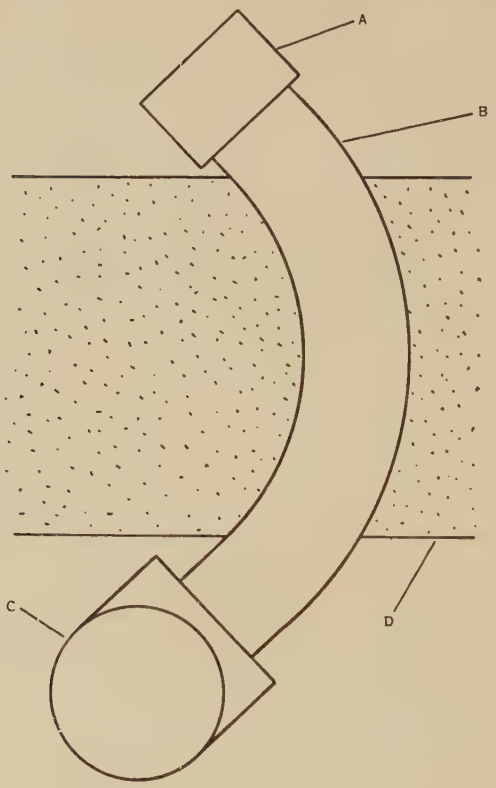

Fig. 5.—Plan showing spray jet in position. *A*, spray jet. *B*, bend. *C*, vertical pipe with valve. *D*, side of circular pond.

VI. A Self-cleaning Inlet Screen

The water in Snobs Creek contains a comparatively large amount of silt, and after heavy rains the amount is very large. At each inlet to the water system three vertical screens, in a concrete box set back from the hatchery race, were used to prevent debris from entering the system. The finest of these screens was 24 gauge, 8 mesh. The screens normally

required cleaning every day, but after heavy rains they needed attention four or five times daily. A self-cleaning screen, incorporating the existing inlet pipe, has been constructed at one inlet and similar screens are in course of construction at the other inlets.

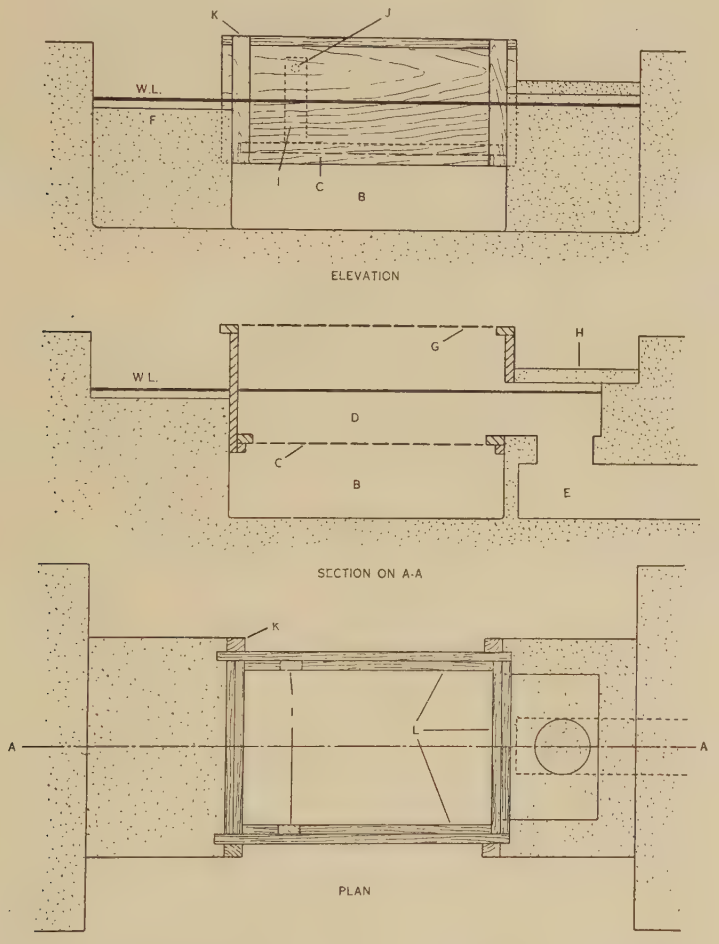

Fig. 6.—Details of self-cleaning inlet screen (covers *G* and *H* removed in plan). *W.L.*, water level of race. *B*, space for water to flow under screen. *C*, horizontal screen. *D*, screen chamber. *E*, 6-in. main to ponds. *F*, spillway. *G*, removable cover. *H*, removable cover. *I*, turn-button holding horizontal screen in position. *J*, screw fixing turn-button. *K*, batten strengthening sides of screen chamber. *L*, battens on which horizontal screen (*C*) rests.

The design of the self-cleaning inlet screen has been determined by the following:

(1) Most debris floats at the surface of the water.

(2) If the cross-sectional area of a water race is reduced at one place the velocity of the water at that particular place will be increased.

Near the inlet the race is approximately 150 cm. (60 in.) wide and 40 cm. (15 in.) deep but at the inlet to the screen most of the water must flow through *B* (Fig. 6) which is approximately 75 by 20 cm. (30 by 7 in.). From *B* some water (approx. $\frac{3}{4}$ cusec) flows up through the horizontal screen (*C*) to *D* and then down the 6-in. main (*E*) to the ponds.

Debris that tends to collect on the screen *C* is scoured off by water flowing comparatively quickly through *B*. A concrete bottom to the race at this place prevents the water, with its increased velocity, from scouring. Floating debris, which tends to collect in front of the screening chamber, passes over the spillway (*F*).

A removable concrete cover (not shown in plan, Fig. 6) over which water may flow during a flood, is provided at *H*. This cover and the chamber beneath it are to be omitted from the newer-type screens but were necessary on the first screen because of existing structures.

Chamber *D*, the sides of which project above flood level, has a removable cover (*G*) consisting of fly wire nailed to a wooden frame, which enables hatchery personnel to inspect the underlying screen (*C*) easily, and prevents debris from falling into the chamber.

Screen *C*, consisting of 24-gauge, 10-mesh stainless steel nailed to a wooden frame, rests on 2.5 by 2.5 cm. (1 by 1 in.) wooden battens (*L*) nailed to the sides of the chamber *D*. The screen is held down in position by two turn-buttons (*I*).

By using a screen of this type, a comparatively fine mesh may be employed at the inlet, which ensures that no debris likely to block other screens is allowed into the pipes of the hatchery system.

VII. Temperatures of Water in Circular Ponds

The temperatures of water in ponds at the hatchery are high during the summer months (24°C. max.). It has been suggested that these high temperatures are primarily due to the shallowness of the circular ponds, and experiments were conducted to ascertain the validity of the suggestion.

The main factors affecting the temperatures of water in a pond are:

(1) Depth of water,
(2) Surface/volume ratio,
(3) Rate of change of water,
(4) Initial temperature of water,
(5) Materials used in construction,
(6) Temperatures of the sides and bottom of the pond,
(7) Temperature of the air above the pond,
(8) Temperature in the sun,
(9) Humidity of the air, and
(10) Wind velocity.

Of these factors little or no control may be exercised over 4-9 once the pond has been constructed although 6 and 7 would be affected if the pond were shaded.

Experiment 16

The flows of water into two identical circular ponds, both with radial-arm jets, were adjusted so that they were equal. The length of the central outlet pipe from one pond was reduced so that the depth of water was less than usual. Water was allowed to flow through the ponds for 90 min. before temperatures were recorded. The flow of water in a third pond, through which water had previously been flowing, was stopped so that the rate of change was zero. Temperatures and other data are shown in Table 20.

TABLE 20

SOME EFFECTS ON THE TEMPERATURES OF WATER IN CIRCULAR PONDS. *A*, CONTROL; *B*, A DECREASE IN DEPTH OF WATER WITHOUT ALTERING THE FLOW; *C*, A DECREASE IN THE FLOW WITHOUT ALTERING THE DEPTH

	A	*B*	*C*
Depth of water (cm.)	23-43	7-28	23-43
Temperature in sun (°C.)	32-33	32-33	32-33
Surface area (sq. m.)	16.7	16.7	16.7
Volume of pond (l.)	4840	2650	4840
Surface/volume (sq. cm./l.)	34	63	34
Flow of water (l./min.)	68	68	0
Rate of change per hr.	0.83	1.53	0
Initial temperature of water (°C.)	17	17	17
Temperature at, or near, outlet (°C.)	18	18	24

When the rate of change was zero the temperature of the water increased rapidly while with a rate of change of 0.83 an increase of only 1°C. was recorded. Where the depth of water had been reduced no increase in the temperature of water at the outlet was recorded. The effect of decreasing the depth was offset by the resultant increase in the rate of change.

Experiment 17

The flows of water into two identical circular ponds, one with a spray jets and the other with a radial-arm jet, were adjusted so that they were equal. Water was allowed to flow through them for 1 hr. before temperatures were recorded. Temperatures and other data are shown in Table 21.

The higher initial temperature of water flowing through the radial-arm jet appears to have been mainly due to the effect of the sun's rays on the metal radial arm. A loss of latent heat may have been responsible for a slight decrease in the temperature of water being sprayed on to the surface of the pond through the spray jet.

From these two experiments it is obvious that no great increase in the temperature of the water normally occurs when it is flowing through the

ponds. The higher temperatures are due, almost entirely, to the high initial temperatures of water entering the pond during the summer period.

TABLE 21

COMPARISON BETWEEN THE TEMPERATURES OF A POND WITH A SPRAY JET AND ANOTHER WITH A RADIAL-ARM JET

	Spray Jet	Radial Jet
Temperature in sun (°C.)	40-41	40-41
Flow of water (l./min.)	72	72
Initial temp. of water (°C.)	20	21
Temperature at outlet (°C.)	21½	22½

VIII. Lethal Temperatures for Brown and Rainbow Trout

Trout in many Victorian rivers are subjected to high temperatures during the summer. It has been suggested that they may be capable of withstanding higher temperatures than those that prove lethal to the same species in other parts of the world.

Experiment 18

Twelve rainbow and 12 brown trout fingerlings (5 cm.), which had been kept in the same pond for 5 weeks, were placed in a shallow pond. As controls a similar number of rainbow and trout fingerlings were placed in another pond, which was filled to a greater depth than the first. The temperatures of the water in both ponds were raised by heat from the sun. When the temperature of the water in the shallow pond reached 29-30°C. all the fry showed signs of distress and died within 30 min. In the other pond where the maximum temperature was 20-21°C. the fingerlings appeared normal. There appeared to be little difference between the effects of the high temperatures on the rainbow and brown trout fingerlings.

Experiment 19

Five rainbow and five brown trout (30-33 cm.) were placed in the shallow pond and, as controls, a similar number of rainbow and brown trout were placed in the deeper pond. When the temperature reached 27-28°C. the brown trout showed signs of distress and died within 15 min., while at 28-29°C. the rainbow trout died within 10 min. In the control pond all specimens appeared normal.

These results agree comparatively closely with those given by Embody (1921) and Needham (1933) and indicate that the lethal temperatures for brown and rainbow trout in Victoria approximate to those for the same species in other parts of the world.

IX. Discussion

Carpenter (1925, 1927, 1930) showed that the death of fish in solutions of salts of heavy metals is due to an interaction between the metallic ions and the mucus secreted by the gills. A film of coagulated

mucus is formed over the gill filaments, which reduces respiration efficiency until the fish are asphyxiated.

Grindley (1946), experimenting with rainbow trout, found that they lost their equilibrium in a solution of $ZnSO_4$ containing 25 p.p.m. Zn within 133 min. and died shortly afterwards even when transferred to fresh water.

Goodman (1951), using solutions of $ZnCl_2$ and $ZnSO_4$ with pH 7.4-7.8, found that 3 p.p.m. Zn was fatal to rainbow trout fry within 48 hr. The fry were obtained from eyed ova hatched in water containing 1 p.p.m. Zn.

Jones (1937), using the stickleback (*Gasterosteus aculeatus* L.) as a test animal, found that solutions down to a concentration of 1 p.p.m. Pb proved fatal over a period of $8\frac{1}{2}$ days. When the solutions were periodically renewed every 24 hr. the lethal concentration was less than 0.1 p.p.m. Pb. Experiments with small sticklebacks gave some indication of slightly higher sensitivity. With zinc the lowest lethal concentration noted was less than 0.3 p.p.m. (for adult sticklebacks). The water used was low in mineral content and had a pH of 6.4-6.6. Jones also found that 50 mg./l. of calcium (as nitrate or chloride) was sufficient to annul the toxicity of 2.0 p.p.m. Zn (i.e. almost seven times the concentration of the original solution).

The experiments show conclusively that in the hatching houses and ponds at Snobs Creek mortality has been mainly due to zinc poisoning. Acid water from the creek dissolves zinc from galvanized-iron pipes of the water system and also from the hatching troughs and trays although they have been treated with aluminium paint. Previous losses in the ponds may have been partly due to dissolved copper from bronze screens but during the present experiments no bronze screens were in use.

Analyses showed that in the hatching houses the concentration of dissolved zinc in the running water was less than 0.05 p.p.m. (typically 0.04 p.p.m.), while in the circular ponds with running water the concentration was less than 0.02 p.p.m. Zn (in some ponds less than 0.01 p.p.m.).

With the exception of Jones (1937), previous workers appear to have studied the effects of metal poisoning on fish only over comparatively short periods, while specimens used by Goodman (1951) had previously been subjected to dissolved zinc and would, therefore, have been less sensitive to the experimental conditions than fish not previously exposed to dissolved zinc.

Grindley (1946) observed that the type of water, concentration of poison, temperature, pH, degree of oxygenation of the solution, and the species, size, and condition of the fish used influence the toxicity to fish of solutions of a given substance. To this list may be added the period of time over which observations are continued, whether the specimens have previously been subjected to the substances being treated, and, when using still water, the intervals at which the test solutions are renewed.

Grindley states that, "the greatest source of error in making tests of toxicity is probably the difference in susceptibility of individual fish to a given poison; it is largely a matter of chance whether the fish taken from the store tank for any particular test are representative samples of the stock as a whole". The author has noted considerable variation in mortality due to zinc poisoning amongst different batches of trout ova, alevins, fry, and fingerlings, and amongst different individuals from the same parents kept under identical conditions. Even when 80 per cent. of a batch died as embryos, some of the survivors grew to 10 cm. fingerlings. It would appear that the differences observed are not due to differences in environmental factors experienced by individual ova or fish, but to individual differences of the ova or fish themselves.

Distilled water used in experiment 1*B* contained 0.02 p.p.m. Zn yet 93 per cent. of the fertile ova hatched. This concentration of zinc in circular ponds, however, was lethal to some ova. In experiments using distilled water, as distinct from the pond experiments, the solution was not being continually renewed.

It would appear that the great mortality produced by such low concentrations of zinc was indirectly due to the very low mineral content of the water and to the fact that ova and fish were subjected to a continuous flow of the poisonous solution for many days.

It was noted that a layer of zinc carbonate formed on the surfaces of galvanized-iron pipe after a short exposure to creek water. Less zinc was dissolved by creek water passing through an old pipe than by a similar flow through a new pipe. When dilute hydrochloric acid was poured down an old pipe, however, some underlying zinc and the zinc carbonate film were removed and a new zinc surface exposed. From this new surface zinc was dissolved by creek water comparatively rapidly.

From observations at some small hatcheries in Victoria, where eyed ova were hatched and the resultant fry released into streams, it is now apparent that early failures were due to zinc poisoning. In these hatcheries the mortality rate has decreased over the years. A recent examination of one small hatchery, where the water has an acid reaction and flows through galvanized-iron pipes, showed that no zinc remains on the inner surface of the pipes. Recently mortality of ova has been relatively small except in one small zinc container used for surplus ova where mortality was 100 per cent.

It is apparent therefore that when galvanized-iron pipes are used in a hatchery water system where the reaction of the water is normally acid, or where it is acid during part of the year, mortality is liable to be great during the first year. Later a film, which is relatively insoluble in water and which partially protects the underlying zinc from the acid water, will form on the surface of the zinc, and the amount of zinc dissolved by the water will decrease. It should be noted that the faster the flow and the larger the diameter of the pipe the smaller the concentration of zinc will be.

If the general pH of the water is lower than normal during one particular hatching season (due to heavy rains or other causes) then the rate at which the zinc dissolves will be greater than usual. During such a season mortality will be greater than usual. Eventually all of the zinc coating will be dissolved from the pipes and mortality from zinc poisoning will cease, although particles of rust, if they lodge on the ova, will cause further mortality.

If live trout are removed from water containing a toxic concentration of dissolved zinc to water that is relatively zinc free, the effects of the zinc may prove fatal to some specimens, at least for a period of 48 hr., even though none exhibited signs of poisoning when transferred. Goodman (1951) noted that some surviving specimens from his experiments showed strong toxic symptoms and could be picked up by hand. In experiments 8-11, however, the survivors appeared normal when released into ponds and could not be caught easily in a net, yet some died later. It is important to realize that, although trout from a hatchery may appear normal when released into a stream, many may die from zinc poisoning if they are carried in unprotected zinc cans containing unbuffered water.

Goodman (1951) noted that *Salvelinus fontinalis* Mitchill and *Salmo trutta* L. were able to withstand concentrations of zinc that proved fatal to *S. gairdnerii* but suggested that their resistance might have been due to a gradual conditioning over an undetermined period of time. The present investigation shows that the lethal concentration of zinc for *S. gairdnerii* is normally lower than that for *S. trutta*.

During experiments no ova hatched when completely covered by silt for the whole period of development. Hey (1940) concluded that the silt in the Jonkershoek water does not adversely affect ova. During the period of his experiments, however, the ova were washed twice. Sheriffs (1933) found that salmon ova hatched satisfactorily under 6 in. of silt in semi-stagnant but well-oxygenated water. Hobbs (1937) concluded that the deposition of fine material on redds affected ova adversely. In the present experiments the embryos appeared to develop normally but died just before the normal hatching period. It is believed that toxic substances, produced from the large amount of decaying vegetation in the silt, were responsible for mortality.

It would appear that the type of silt, rather than the amount, is the factor that determines whether ova will be adversely affected or not.

X. Conclusions

(1) In acid waters with a very low mineral content 0.01 p.p.m. Zn is toxic to ova and alevins of brown and rainbow trout.

(2) All stages in the life history of rainbow trout are normally more susceptible to zinc poisoning than corresponding stages of brown trout.

(3) Trout survivors that have recently been subjected to toxic concentrations of dissolved zinc are less sensitive to further toxic concentrations than specimens that have not previously been in solutions of zinc.

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THE TOHEROA, *AMPHIDESMA VENTRICOSUM* GRAY (EULAMELLIBRANCHIATA), DEVELOPMENT AND GROWTH

By A. M. Rapson*

(*Manuscript received November* 29, 1951)

Summary

A short historical account of the toheroa of New Zealand is given, and its beach habitat is described. Development of the reproductive organs, spawning, and early development are described up to the stage when the free-swimming form settles on the beach. Types of sand and the particular character of the zone in which toheroa are found are described. Length frequency data and shell zones are used to demonstrate differences in growth rate on the four principal beaches. Length frequency data are shown to give a much higher rate than shell zones indicate, probably because of the long spawning season. Growth of different parts by weight is studied. Of several hundred toheroa marked with a file, two were recovered after 6 weeks, giving a growth rate in agreement with that estimated. One small specimen kept in an aquarium for 8 weeks made no growth. The existence of off-shore stocks is briefly discussed.

I. Historical

In the eighteenth century Maoris were living in large numbers on some of the North Auckland west coast beaches cultivating sweet potatoes and catching fish and shellfish. The extensive shell deposits to be found in the sand dunes today bear testimony to the use made of shellfish, but the presence of tuatua (*Amphidesma subtriangulatum* Wood) in many of the shell heaps indicates that even at this early time toheroa (*Amphidesma ventricosum* Gray) were not always plentiful, and the beds possibly became reduced to such a degree that the Maoris were forced to seek their food in other parts.

Toheroa figure large in Maori mythology and were according to this brought to New Zealand by one Mareoa, who planted them on the west coast. Reproduction was believed to take place in the herbage along the shore, the small shellfish forming in the seed heads of such dune plants as marram or beach grass (*Spinifex hirsutus* Labill.), whence they were transported to their proper position on the beach in the spring when the shining seed heads were blown seawards by the easterly winds. Children were not allowed to play their game of waiwatai, in which the seed heads were chased as they were blown over the sand, when transference of seed toheroa was considered to be taking place. Less plausible variations of this theory record young toheroa flying in dense swarms from sand dunes to the sea. Stallworthy (1916) records the legend of how five Maoris in order to obtain food supplies left the east coast on what must, at the time, have been rather a hazardous journey to the toheroa

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beds on the west coast; all went well until the Wairoa River was reached, when four were drowned attempting to cross. The fifth man, who crossed safely, is remembered by a green hill near where he landed which bears his name, Motu Whetekei, to this day. For preservation and easy transport toheroa meats were cooked in the hongi or Maori oven, then threaded on strings and sun dried. It is probable that some of the Maori success in waging wars was due to their food supplies of dried shellfish.

Europeans were not seriously interested in toheroa until the end of the nineteenth century, by which time the Maori had come to respect their ways and there were plenty for both Maori and Pakeha on the main beaches, but at Miti Miti, where small numbers of large ones occur, the taking of a few by a visiting party during a Maori close season caused a serious situation, which could have ended in tragedy, the matter being finally settled lawfully.

Successful canning was achieved about 1900 and within a few years four factories were operating on the 12-mile stretch of the North Kaipara beach between Glinks Gap and Baileys Gorge (see Fig. 1). This beach always has good beds but the dangerous nature of the coast, with rocky parts and inaccessible cliffs, makes it the most difficult of all the beaches to work, so that after a few seasons only one cannery remained to operate the favourable area to the south; it has continued to the present time, with only occasional stoppages because of shortage of supplies. Digging on this beach has been in a most rational manner, strips 1-2 yd. wide and a yard apart being dug across the bed. This thinning appears to have a beneficial effect on all beds but particularly on the dense ones, where sometimes the shells are packed so tightly together that they become misshapen. Only a small percentage under $3\frac{1}{4}$ in. long is included in the commercial digging. Toheroa on this beach grow over $2\frac{1}{2}$ in. in the first 12 months and although growth in length is less the following year, increase in weight of meat is proportionally greater. The principal growing season is May to September, which covers the canning period, so that it is profitable to dig the beds more than once a year. Prince (1914), reporting on the toheroa, suggested a rotation of open and close seasons for sections of the beach several miles long and reserve areas for small toheroa. The system of strip digging that has operated on the North Kaipara appears to be satisfactory and the method could well have been adopted on the Ninety-mile Beach.

Canning on the Ninety-mile Beach did not commence until 1923 and it appears that digging beds completely from end to end was inaugurated early. The small toheroa included in the commercial catch reached 15 per cent. under 3 in. by 1940 and in 1945 commercial digging ceased because of the absence of supplies.

By 1942 stocks of toheroa on the Muriwai beach had appreciably increased after the 1938 mortality, and commercial digging for canning was started in 1945 for the first time. Only a part of the best section of the beach was dug; the method of leaving strips of beach 1 yd. wide was

adopted although some toheroa under 3¼ in. long were taken. There has been little marketing of fresh toheroa; only small amounts reached Auckland in the late 1920's. They are recorded as selling at 1d. each in 1927 and 2d. each in 1930, although there appear to be good prospects of marketing fresh ones in Auckland during cool weather.

Fig. 1.—North Island of New Zealand, with localities mentioned in text.

Attempts to develop more beds by transplanting to localities where toheroa are absent or only rarely found have not been successful. Numerous small lots have been taken across the North Auckland isthmus to the east coast but no beds have ever developed. An experiment on a large scale in 1927 was believed to have established toheroa in the Bay of Plenty but they existed there previously.

The four principal beaches are the Ninety-mile, North Kaipara, South Kaipara or Muriwai, and the Wellington west coast south of the

Manawatu River. Small numbers also occur in other places, of which the most important are Miti Miti near Hokianga, and at Tewae-wae Bay on the north shore of Foveaux Strait in the South Island where, however, only small-sized toheroa are found. They have been reported also at Spirits Bay and Tom Bowling Bay on the extreme north coast of the North Island and on the east coast at Tokerau beach and Te Arai. In these last two places they were possibly planted.

The data recorded here were collected during the years 1935-46. The principal work was done following the catastrophic mortality in 1937-38, but observations were made whenever possible until 1946.

II. Description of Beaches

Toheroa occur from 34½ to 46½° S. latitude, which includes part of the subtropical and subantarctic regions. The inshore sea temperatures over this distance vary from approximately 40 to 80°F. but air and wet sand are from freezing point to over 90°F. On the North Auckland beaches normal temperature ranges from 55 to 65°F. The prevailing westerly winds drive a heavy surf on the beaches except during the spring, when easterlies occur, mainly in October, and blow sand from the dunes onto the beach, as much as ¼ in. being deposited in 3 hours in a normal wind and gales blow much more; small toheroa near high water are often deeply buried and sometimes do not survive. Considerable movement of sand along the beach occurs — usually northwards. Sometimes rocks in the North Kaipara are exposed to a height of 6 ft., only to be completely covered again several weeks later. The toheroa during this period are to be found in the immediate vicinity of the rocks. At other times gales wash out runways and channels along the beach and have completely removed whole toheroa beds; this is rare, as the toheroa zone is narrow relative to the width of the beach. The beaches are in places extremely wide, usually over 100 yd. to low water and often over 300 yd. The zone normally occupied by toheroa is 5 to 50 yd. wide at the level of half tide but the slope of the beach at this level is peculiar in being somewhat more steeply shelving than the low-water zone below it. Above the beds the beach may slope more steeply than the section bearing toheroa (when the bed is usually narrow) or less steeply, which is normal when it may be wide. The effect of this increase in slope in the toheroa zone is to create an area where the surf pounds harder and possibly leads to a greater oxygenation. Absence of surf in any case brings an immediate lessening of activity in the toheroa. The levels of beach from three good toheroa beaches as given by Abney level measurements are recorded in Table 1.

The Wellington beaches are somewhat exceptional in that they shelve more evenly and occurrences of toheroa on them are more irregular.

Water that seeps onto beaches from sand dunes usually appears first in this mid-tide zone except in unusually dry periods. Toheroa do not thrive unless there is ample seepage water and when it does not

occur they are seldom found as the sand becomes very hard, although large numbers in a bed have the power of holding in the shell a quantity of water, which keeps the beach moist and soft, a necessity perhaps related to their breathing movements when the tide leaves the beach uncovered. Freshwater lakes or shallow lagoons occur behind the sand dunes on most beaches — they were believed to be reservoirs of water that appeared as seepage on the beach, but evidence does not always support this theory. Many disappear in dry seasons and lessened seepage and consequent diminution in toheroa supplies caused the lakes to be regarded as vital to the occurrence of toheroa beds, but the volume of water running onto the beach as seepage water is very great indeed and small springs below half-tide level are not unusual. Sometimes dry weather reduces the seepage water long before the lakes are dried, which indicates

TABLE 1

GRADIENT OF BEACH IN TOHEROA ZONE AND ABOVE AND BELOW IT

Distance North of Waipapakauri Road (miles)	Low Water to Bottom of Toheroa Bed		Toheroa-Bearing Beach		Top of Toheroa Bed to High Water	
	Distance (yd.)	Slope	Width (yd.)	Slope	(yd.)	Slope
9.7	124	1 in 81	23	1 in 45	68	1 in 61
13.3	153	1 in 71	11	1 in 25	71	1 in 80
15.4	165	1 in 77	36	1 in 47	49	1 in 32

an independent source. Toheroa are able to withstand dry conditions for some months, but they gradually disappear when the beach is dry and hard. Although the seepage water at the depth of toheroa in the sand is often drinkable, the liquid inside the shell is of the same salinity as the sea, as the mantle completely closes the gaping shells.

Often in feeding the toheroa is covered by only a few inches of water, and as plankton organisms are taken in immediately the first wave covers the beds the effect of this is that fine sand grains are taken in with the food, as, although the large grains are actually not washed about very much, some small particles of sand are always to be found even when there is only a small movement of water. This mixing of fine sand and phytoplankton is one of the reasons why toheroa do not thrive or are absent from many beaches that in other respects are quite suited to their requirements.

The records in Table 2 of sizes of sand from different positions are of interest in relation to this. A sample comprising 20 grains was measured, an average of two diameters for each grain being taken; some extreme sizes are given. Small shell particles were rarely present on sandy beaches and sand was not found on some parts of the Rangitikei beach where fine shell and shingle predominate over long stretches.

The west coast beaches extend almost uninterrupted for many miles, Muriwai for 30, Ninety-mile for 55, and the North Kaipara for 45 miles

without any appreciable change in direction, yet at high water mark they are not straight, there being a small bay every 100 yd. or less; at the ends of the bay are slight ridges or promontories of sand — hard enough after spring tides but soft after neaps which do not cover the ridges. The toheroa beds occur within these bays and only when exceptionally great numbers are present do the beds become continuous or extend into the adjoining bay. This type of beach formation is most conspicuous on Muriwai and Ninety-mile and the southern part of North Kaipara. It is not impossible that the toheroa have some effect on the configuration of the beach as in large concentration their movements cause the sand to be loosened considerably and thus washed away by the surf, but the beach in many beds under observation has remained constant for some years, toheroa beds continuing to occupy the identical positions.

TABLE 2

AVERAGE SIZE OF SAND GRAINS FROM TOHEROA BEACHES AND OTHER PLACES; EXTREME SIZES IN BRACKETS

Locality	Size of Sand Grain (mm.)	Remarks
Ahipara, Ninety-mile Beach	0.34	Toheroa seldom found
North of Waipapakauri	0.24 (0.42)	Good bed (one)
North of Mangonui Bluff	0.26 (0.16)	Poor beds (1940)
Glinks Gap, North Kaipara	0.27	Good beds
Muriwai beach, 28 miles from road	0.22	Poor beds
Muriwai beach, 5 miles from road	0.27 (0.52)	Good beds
Muriwai beach, 1 mile from road	0.16	Poor beds, iron sand
Wellington, 1 mile south of Manawatu River	0.22	Fair beds
Waikanai–Te Horo	0.21 (0.48)	Fair beds
Exceptional surface, Cook Strait, tow netting in 30 fathoms, net 180 meshes per in.	0.11	
Rangitikei beach, very fine shingle and sand	—	Not bearing toheroa
Wanganui beach, iron sand	—	Toheroa will not thrive

At Glinks Gap, a seaside resort on the North Kaipara, the beds are of particular interest as they are in the centre of an extremely productive part of the beach. Every year many thousands are taken close to the residential area. To the south, the cannery operates in the winter over an area bounded by sand dunes, but to the north are precipitous sand cliffs, some over 100 ft. high, extending beyond Baileys Gorge; at high tide the sea washes the base of these cliffs. Although the first 12 miles are well stocked, the beach in the northernmost 10 miles becomes more rocky and does not usually bear many good beds. Figure 2 shows the position of beds on the beach at Glinks; such a diagram is applicable to any good toheroa beach. Freshwater streams may be completely absent

as for all the Muriwai beds, but the position of the main areas of large and small toheroa is the same, small ones being found only at the correct season. Up to 3-4 mm. long they are widely scattered over the beach and until they reach about this size may be to some extent free-swimming. They early form into beds, usually near high water and remain above the main beds until over an inch long. Sometimes beds of toheroa a few months old are not covered by neap tides for several days, and in cool weather suffer no ill effects but, if the sand dries, the whole bed may

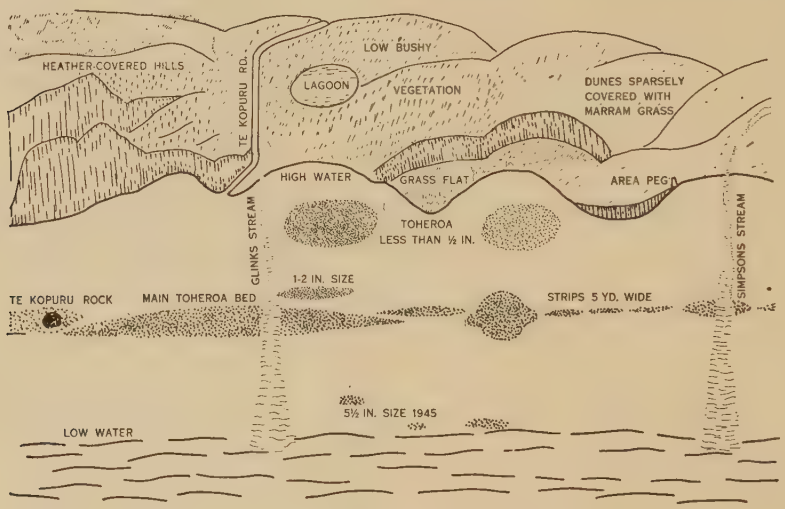

Fig. 2.—Diagrammatic plan of toheroa beds at Glinks Gap on the North Kaipara. (Not to scale.)

be killed. Often toheroa $1\frac{1}{2}$-3 in. long are in beds completely separated from the larger ones, but when they occupy the same bed the smaller form a layer slightly above the larger, which may have "dug in" 6 in. or more.

III. Development

During the spring, summer, and autumn of 1938-39 conditions on the North Kaipara beach were favourable for the study of young stages. Few toheroa under $1\frac{1}{2}$ in. long were to be found but spawning started in October 1938 and continued without interruption until June 1939. Young stages were obtained by tow netting in the surf in two periods, viz. November 1938 and February 1939. That spawning was continuous and not periodic was shown by length frequency data.

The conditions in the sea during this period were a moderate phytoplankton and small quantities of zooplankton including a succession of small scyphozoans, ctenophores, salps, and crustaceans. The quantity of phytoplankton present, high by comparison with the open ocean but low compared with the great development in winter, was sufficient to keep

the toheroa fat during this period, in which they are sometimes in poor condition. A net of bolting silk, 180 meshes per inch, was used to collect larvae which, because of the small amount of phytoplankton, were easily

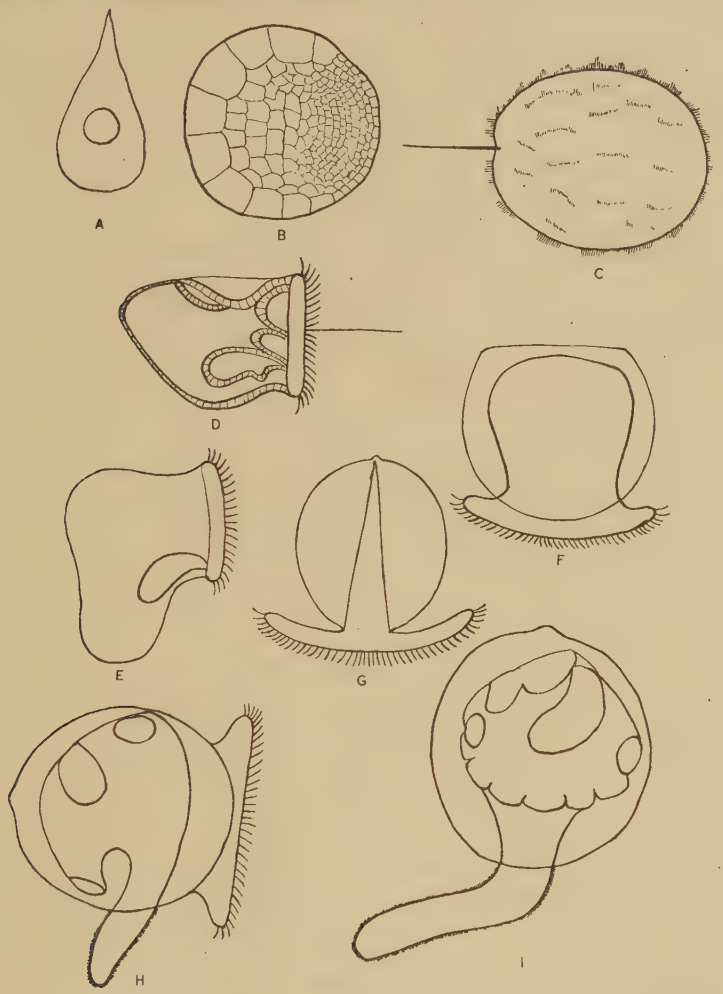

Fig. 3.—*A*, egg 0.6 mm. diameter. *B*, embyro 6 hours after fertilization, early blastula. *C*, 20 hours after fertilization, with flagellum. *D*, 36 hours after fertilization, late gastrula before losing flagellum. *E*, 48 hours after fertilization, development of foot or tongue. *F* and *G*, 3 days after fertilization, veliger with mantle expanded (shell 0.14 mm. in diameter). *H* and *I*, larvae from the sea with mantle expanded in swimming position and "burrowing". Shell 0.38 mm. diameter.

observed. Dense phytoplankton, however, does not prevent spawning or the successful settling of larvae. During this long spawning season on the North Kaipara seepage water from the sand dunes and cliffs kept

the beach sufficiently soft and moist when left uncovered by the tide for both small and large toheroa to burrow freely. Moderate to light surf and tides also prevailed so that there were no major changes in configuration of the beach; this appears to be of major importance in the settling of small toheroa but subsequent observation leads to the conclusion that light surf may be serious for the large ones in contributing to mortality.

Artificial fertilization in half-gallon glass aquaria was attempted many times, but development proceeded satisfactorily only on one occasion, when larvae were kept alive for 4 days. The water in the aquaria was aerated every 6 hours by using a 2-oz. rubber pipette bulb to force air through a beech-wood plug at the end of a rubber tube. The young toheroa appeared to be growing well after the shell developed but the experiment was concluded when the larvae remained on the bottom of the aquaria. It was subsequently found that they normally react in this way in daylight and the burrowing habit is almost certainly developed partly as a reaction to light.

In the sea the earliest shelled stages are kept in constant movement by the surf and do not settle on the beach until about 1/10 in. long; even then the foot or tongue is as long as the shell and appears like an enormous "ciliated flagellum", which at this stage keeps the animal in constant movement when it settles on the sand, until it is able to bury itself completely. Some of the early stages of development are shown in Figure 3, and Figure 4, *A-G*, shows the changes in shape of the early shells.

The egg is an elongated pear shape when ripe; after fertilization it becomes almost spherical, the first cleavages are regular, making two and four cells (by vertical cleavages) forming polar bodies. The eight-celled stage results from a horizontal cleavage. After 6 hours an almost circular blastula is formed with distinctly larger cells on one side and at 16 hours invagination to form the gut and liver has commenced. Up to this stage the embryo sinks, but it now becomes ciliated and swims freely. At 24 hours a rodlike flagellum appears opposite the opening of the blastopore and this is usually directed forward in moving; only the extreme tip appears to be used as a flagellum. It exists for only about 20 hours, during which time it comes to be in the centre of the ring of cilia surrounding the mouth. At one stage the motion of the blastula appears to be in a spiral because of the asymmetric position of the flagellum. Cilia do not cover the blastula evenly but are in numerous short rows, which are sufficiently close together to give the outline the appearance of being completely ciliated. Before it disappears the rodlike flagellum makes the movement of the embryo look clumsy. Much of the movement of the animal is produced by the cilia and when the flagellum disappears the movements become faster. In the veliger stage the hind part of the body is composed of thin cells while the body wall furthest from the foot is composed of large cells like the three diverticula of the gut. The largest of these three diverticula appears to be the rudiment of the liver; it soon

becomes green coloured in the embryo and in the adult extends over a large part of the body. No observations were made on subsequent internal development but one of the diverticula probably forms the sac enclosing

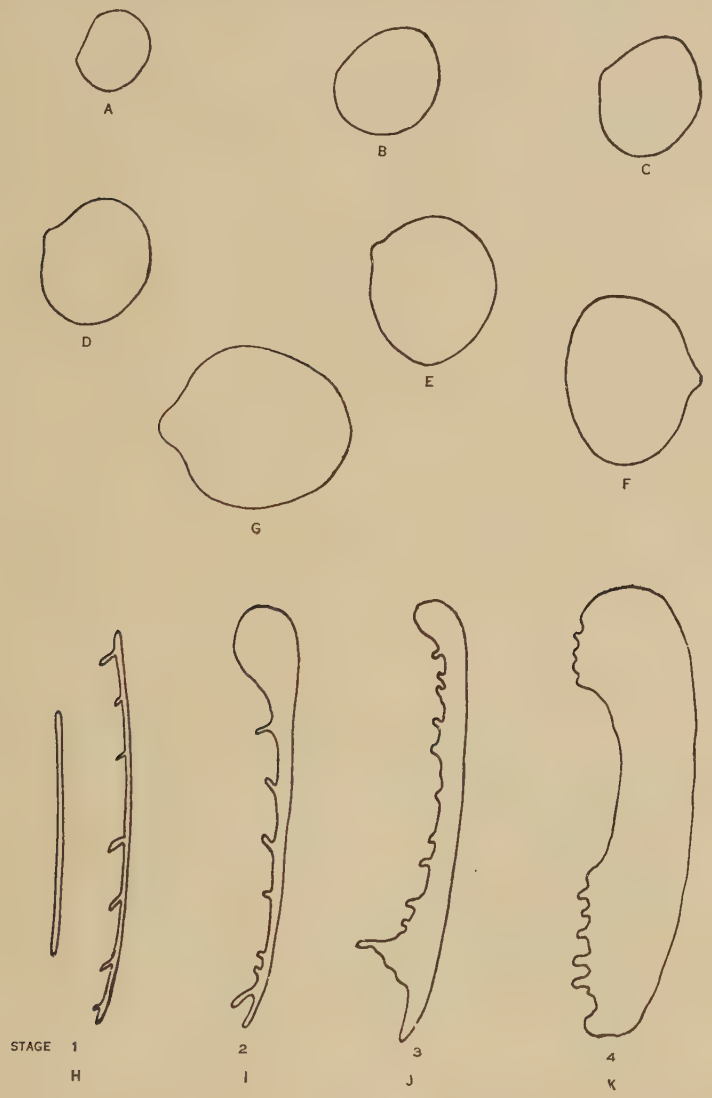

Fig. 4.—*A-G*, early shell shapes. *A*, 0.14 mm. *C*, 0.16 mm. *E*, 0.24 mm. *G*, 0.41 by 0.44 mm. *H-K*, Development of reproductive organs, stages 1-4.

the crystalline style, which in the adult extends from almost the end of the tongue to a diverticulum of the stomach, and is almost as long as the body (Fig. 5*I*). The crystalline style is non-cellular, and may be a secretion of the cells of the diverticula. The end of the style, which enters the stomach, always appears rounded as if the style rotated and

was worn away. It is probably of use in digestion of the silica shells of diatoms, which are broken down very quickly, the stomach contents being

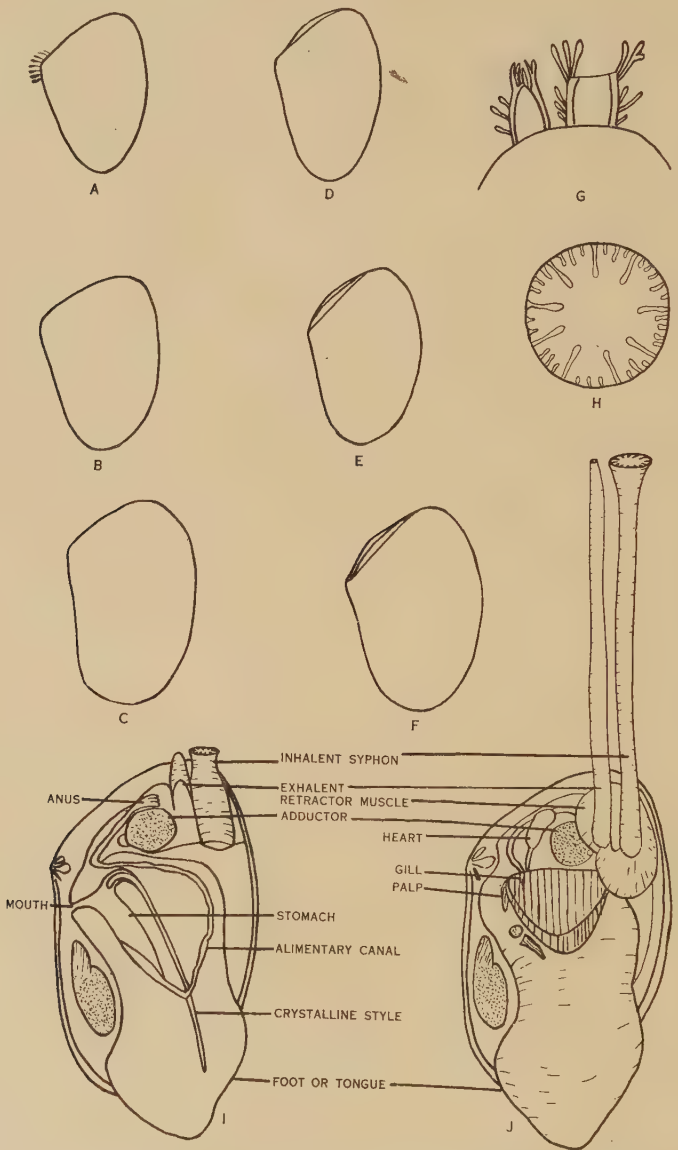

Fig. 5.—*A-C*, tuatua 4, 15, and 55 mm. long from Wellington. *D-F*, toheroa 4, 15, and 55 mm. long from North Kaipara. *G*, siphons of 4 mm. toheroa. *H*, inhalent siphon of slightly larger size (plan). *I*, internal organs. *J*, shell and mantle only removed.

unidentifiable about half an hour after feeding. The rudiment of the shell develops as a rather translucent area near the flat part of the embryo

furthest from the velum and the veliger becomes almost boot shaped before the shell can finally enclose the whole animal. The manner in which the shell developed was not at all obvious; it appeared in a transparent area on each side somewhere near the position where the adductor muscle might be expected in the adult, but no sign of muscle was seen and the shell appeared merely to grow over the body. The mantle developed greatly as the shell to support the animal grew, giving the impression that the shell, until a quite late stage in the larval development, was not able to enclose the larva. The ring bearing cilia in the veliger persisted and became expanded to form the mantle.

Cilia were not observed on the foot-like outgrowth of the veliger, but in the earliest larvae taken in the sea, the veliger-like characteristic persisted and the larvae were extremely mobile. At this stage when the embryo was observed lying on the sand, the foot or tongue, as this organ has come to be called, when extended had become almost as long as the shell and quite needle-like; it appeared ciliated and could be thrust in and out among the sand grains with great rapidity, although it appeared quite impossible that the embryo at this size could bury itself in the sand. Although much search was made, none of this stage was found in sand on the shore. The habit of young toheroa of sinking in water at this early stage is not significant as the surf would normally keep them in motion. It is unlikely, if left by the tide, that they could withstand the pressure of sand grains. The earliest shelled stages found on the beach were 2 mm. long and only a few dead shells of earlier stages were found.

The total time the North Kaipara toheroa spent in the sea from egg to small toheroa is probably between 10 and 12 days; all live toheroa found on the beach had a shell of typical adult shape.

Small toheroa cannot be distinguished from the tuatua, and only the absence of any beds of the latter species on the North Kaipara beach made certain the identification of toheroa larvae. On the Ninety-mile Beach small tuatua had a byssus-like growth, which appeared to attach to sand grains, but this was not found in specimens from further south. No byssus hairs or thread were found in the toheroa. The shell of toheroa may be distinguished from tuatua by the pallial line and in animals $\frac{1}{4}$ in. long by the more rounded shape and rough shell; tuatua have shiny, smooth shells (Fig. 5, *A-F*).

On the Wellington west coast beaches somewhat different conditions to those on other toheroa beaches prevail; the surf is much less and few toheroa under 2 in. are to be found. The young stages remain off shore for a considerable time, and the large ones, too, appear to move from the beach to below low tide at irregular intervals.

IV. Development of Reproductive Organs

The reproductive organs make their appearance as two white, tubelike streaks one each side parallel to the crystalline style. Sometimes they

are obvious in shellfish ½ in. long but may not be found in toheroa 2½ in. in length; from the first tube, follicles grow out over the body and may come almost to cover the gut completely, but they do not extend over the extreme tip of the tongue, which has many cavities, normally filled with body fluid, which makes a slight swelling and serves to anchor the animal. Much of this white body fluid is lost when the toheroa is removed from the sand. It has never been found to contain reproductive cells, which appear to be extruded through small pores near the exhalent siphon. In the male the gonads may be a pale brownish pink but usually in both sexes they are pale cream. Sometimes the male may be distinguished by the gluey nature of the reproductive cells, which separate with some difficulty in sea-water, while female cells are granular and can be readily seen.

Figure 4, *H-K*, shows four stages in the development of the gonads. It is considered that no reproduction takes place before stage 3 (Fig. 4*J*) is reached; this occurs usually in the second year, but the quantity of reproductive cells from young toheroa is estimated to be less than 1/100th that from the old stock (based on loss of weight after spawning).

The two types of development of the gonad occur:

(1) The gonad develops over the visceral mass and is composed just prior to spawning almost entirely of ripe cells. This is the usual type of development and with a few exceptions all mature toheroa are of this type.

(2) Mature sex cells are present in follicles which, although they are present over the whole of the body, appear to be scattered through a layer of "fatty" tissues. This has been observed only on the North Kaipara beach, but probably occurs whenever toheroa are fat.

In the first type all reproductive cells are spawned within a short period and the body weight may become reduced by as much as 50 per cent., while in the second type, if feed is abundant, the shellfish actually increases in weight.

Artificial fertilization was successful only with toheroa of the second class although no differences could be detected in the eggs, which are quite constant in size and shape from a very early stage; toheroa from ½ to 5 in. are found with eggs of the same size and shape. Prior to spawning the eggs are often packed tightly together and become somewhat angular in shape. In the male the sperm mother cells are round and slightly smaller than the eggs.

In the three months November 1939, March and August 1940, a large number of toheroa under 3 in. long were examined to determine the proportion which became mature and to detect differences in spawning times on the three North Auckland beaches. The principal results were that no significant differences occurred in the number that became mature at any particular size but that there were more mature under 3 in. on

the North Kaipara, despite the fact that they grow faster on this beach. All toheroa over 3 in. long were found to have the gonads developed to at least stage 3 and in some spawning had occurred. Neave (1944) shows that the butter clams mature at about $1\frac{1}{2}$ in. in length although age on different beaches varies from less than 3 to nearly 5 years old at this size.

V. Times of Spawning

In December 1937 spawning was finished on the Muriwai beach and in November 1938 spawning occurred. In November 1938 spawning started on the North Kaipara and continued for 8 months until at least June 1939. It commenced again in November 1939 and continued until at least March 1940, and started again in June and continued until August 1940.

Fewer accurate observations are available for the Ninety-mile Beach, where serious depletion had occurred by 1938. Spawning took place on the south end in November 1939, but did not occur north of Mangonui Bluff at this time.

Less information is available for the Wellington beaches where the almost complete absence of young stages on the beach makes it impossible to determine if successful spawning has taken place. Toheroa here are usually fat until August, and spawning probably occurs between July and September, but it may vary as on the North Kaipara. Some early stages of development were obtained by artificial fertilization in December 1940.

No reasons for the extremely irregular spawning have been found but the evidence suggests that when toheroa in northern waters are fat they spawn, and, if suitable food is available for the larvae and conditions on the beach are right, the swarms of young settle on the beach, first scattered irregularly, then in small patches that change position, but ultimately become established with some degree of permanence in the half-tide zone. That the young, shelled stages occur in swarms is shown by the extremely limited distribution of the young, which, at a size of only 2-3 mm. long when they are ready to settle on the beach, may be seen in quite limited areas, washed out by each big wave.

VI. Growth in Weight

In the measurement of growth, lengths give much better data than weights, which vary considerably with a given length, e.g. a broad shell $4\frac{1}{2}$ in. long may weigh more than a narrow one of $4\frac{3}{4}$ in. length. Weymouth, McMillin, and Rich (1931) give the following facts for the clam *Siliqua patula*, which are largely the same for the toheroa: "The mantle cavity contains a varying quantity of liquid which may or may not be lost at the time of digging. The sexual products also may comprise 10-30 per cent. of the total weight so a further error is introduced." The mantle cavity of the toheroa may also contain an appreciable quantity of sand.

Weights recorded here were collected in the first instance for estimation of quantities available for canning, but they show also interesting information on feeding, reproduction, and growth of different parts. Data given in Table 3 show the proportion of edible meat to total weight etc. In the samples included, none contained sand in the mantle cavity or had lost an undue proportion of liquid. Weights were taken in $\frac{1}{8}$ in. groups to avoid sampling error; e.g. the weights given at $2\frac{3}{4}$ in. represent shellfish between $2\frac{5}{4}$ and $2\frac{7}{8}$ in. In general there is proportionately more meat in small toheroa, but the labour of collecting is great. It used to be customary on some beaches to gather pipi toheroa which were considered to be better flavoured and more tender.

TABLE 3

WEIGHTS OF SHELL, LIQUOR, TOTAL MEAT (SYPHONS OR NECKS, MANTLE, MUSCLES, ETC.), AND EDIBLE MEAT IN TOHEROA 2-5 IN. IN LENGTH. NORTH KAIPARA, NOVEMBER 1938

Length (in.)	Total Weight (oz.)	Weight of Shell (oz.)	Weight of Liquid (oz.)	Total Meat (oz.)	Edible Meat (oz.)	Edible Meat/ Total Weight (%)
2	0.5	0.25			0.12	28
$2\frac{1}{4}$	0.8	0.35			0.22	27
$2\frac{1}{2}$	1.1	0.50			0.27	24
$2\frac{3}{4}$	1.5	0.65			0.37	25
3	2.1	1.0	0.16	0.91	0.58	27
$3\frac{1}{4}$	2.6	1.3	0.33	1.0	0.62	23
$3\frac{1}{2}$	3.3	1.6	0.39	1.2	0.79	23
$3\frac{3}{4}$	4.2	1.8	1.1	1.6	0.91	22
4	5.3	1.9	1.3	2.0	1.2	22
$4\frac{1}{4}$	6.1	2.5	1.2	2.3	1.5	24
$4\frac{1}{2}$	7.1	2.9	1.6	2.5	1.7	23
$4\frac{3}{4}$	8.8	4.1	1.8	3.0	2.0	22

The quantity of edible meat varies from 28 per cent. in small ones to 22 per cent. in large. The great increase in total weight is largely due to the shell, which increases about 20 times in weight between 2 and 5 in. and five times between 3 and 5 in. The weight of liquid also increases considerably. Total meats increase about four times and edible meats somewhat less.

Chen and Kao (1936) gave the increase in weight of clams 15-27 mm. long in periods of 30, 60, 80, and 100 days as 9, 18, 40, and 60 times respectively, the original weights, which varied from 0.13 to 0.66 g. No comparable data for toheroa of this size are available, but the rates of increase are similar. Table 4 shows the increase in weight of edible meat.

Toheroa 1.3 in. long at 8 months old increase to 10 times the initial weight 12 months later.

Fifteen records of weight show some important differences:

(1) The weights on Muriwai and Ninety-mile vary more than on the North Kaipara.

(2) Toheroa under 3 in. vary less than those over 3 in.
(3) When the edible meat drops to 0.55 oz. in toheroa $3\frac{1}{2}$ in. long, mortality may be serious — one of 0.75 oz. is fat at this length.

TABLE 4

INCREASE IN LENGTH AND WEIGHT OF TOHEROA ON THE NORTH KAIPARA BEACH

Date	Average Size (in.)	Estimated Weight (oz.)	Proportionate Increase in Weight
August 1939	1.32	0.08	—
November 1939	1.87	0.16	2.0
April 1940	2.60	0.37	2.3
August 1940	3.46	0.86	2.3

(4) The average weight of meat on the North Kaipara is higher than is usually found in good toheroa in other places, including the Wellington beaches.

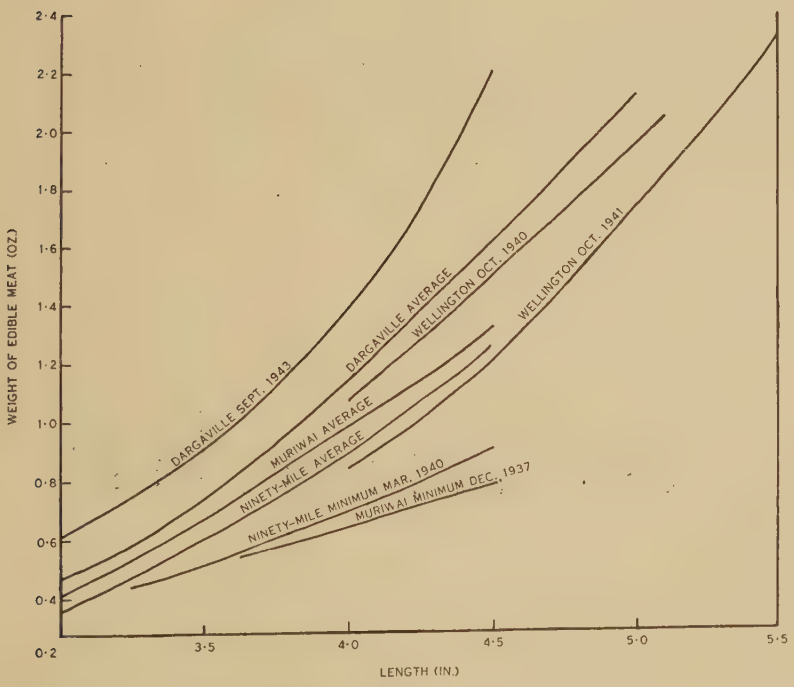

Fig. 6.—West Coast beaches. Weight of edible meat of 3-5 in. toheroa.

(5) In the period December to May weights are below average and in June to November above average.

Figure 6 shows the variations in weights of edible meat from the four main beaches. Detailed data for Muriwai in Figure 7 show the

extreme variation in summer and winter and some low weights in spring, which is considered the best canning period. Table 5 shows the differences in weight of toheroa from four beaches.

TABLE 5

AVERAGE TOTAL WEIGHT OF TOHEROA (OZ.). MARCH AND APRIL 1940

Length (in.)	Ninety-mile	North Kaipara	Muriwai	Wellington
3	1.9	1.9	2.0	
3¼	2.4	2.5	2.6	
3½	3.0	3.2	3.3	2.9
3¾	4.1	4.1	3.7	3.8
4	4.7	4.7	4.4	3.9
4¼	5.6	6.0	5.7	5.2
4½	6.6	7.0		6.0
4¾				6.5
5				9.1

VII. GROWTH RATE

Hefford (1927)* of the North Kaipara toheroa says, "From observations made at the beginning of 1925 and again in the past year it appears probable that these molluscs grow approximately one inch every year" and in 1928, referring to the Muriwai, North Kaipara, and Otaki beaches, "results obtained confirm indications from last year's observations that the average annual increase in length of the shell of this species is approximately one inch".

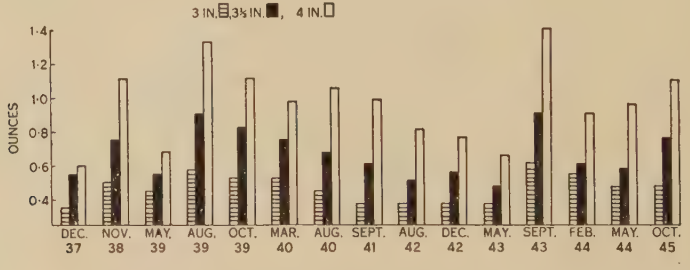

Fig. 7.—Muriwai beach. Average weight of meat in 3, 3½, and 4 in. toheroa.

Cassie (1951) states that the age is proportional to the square of the shell length but gives no constant. From the limits of length and age given growth must be about 2 in. in 12 months and 4 in. in 4 years; figures that may be obtained from combined data from North Kaipara and other beaches (see Table 9). Such a formula, however, would not be very accurate for shellfish less than 1 in. in length as it implies a rate

* The full reports giving data on age appear in the appendices to the Annual Reports from 1927 to 1945.

of growth about an inch in 3 months. These workers probably experienced difficulties in finding the early shelled stages which have been found most useful in determining growth rate on the North Kaipara.

At Glinks Gap in November 1938 there were a few toheroa between $\frac{1}{2}$ and $1\frac{1}{2}$ in., but many less than $\frac{1}{4}$ in. occurred. Observations were made on this brood every 3 months until November 1939 and again in March and August 1940. They were easily distinguished from other spawnings by length frequency measurements. Appendix I gives length frequency data for North Kaipara in November 1938 and the data of the 1938 brood at Glinks are given in Appendix II. Measurements were made in $\frac{1}{4}$ in. intervals until 1938, when many were made in millimetres; $\frac{1}{8}$ in. intervals were subsequently adopted as they could more easily be compared with previous records.

In November 1938, 60 per cent. of the small toheroa found were less than 3 mm.; all were obtained by allowing seepage water to collect in holes dug on the beach and then flow out as a small stream, wasting away a thin layer of sand. Toheroa uncovered were quickly picked up before they buried themselves again. Only sufficient of these very small ones were collected in subsequent months to prove that spawning was continuing so that the length frequency data are not truly representative in respect to the numbers on the beach, but after 1938 collections are comparable in other respects. They were collected by taking the surface $\frac{3}{4}$ in. layer of sand with a broad, pronged fork and throwing it over the beach, making toheroa separate from the sand and be easily seen. The data show conclusively the extended spawning season, and for this beach the rapid rate of growth. The fastest growth occurs in the first 3 months when a maximum length of about an inch is reached, $1\frac{5}{8}$ in. in 6 months, $2\frac{1}{4}$ in. in 9 months, and nearly $2\frac{1}{2}$ in. in 12 months. Modal sizes in 3-monthly groups are $\frac{3}{8}$, $\frac{3}{4}$, $1\frac{1}{4}$, and 2 in. The average age of the 2 in. size is about 9 months. In March 1940 the mode was $2\frac{5}{8}$ in. and in August $3\frac{3}{8}$ in. The average age in August is 18 months, which represents a growth rate of nearly 1 in. in 5 months.

The monthly growth rate calculated from data in Appendix II is given below for Glinks. As measurements were recorded to the size below the actual measurement 0.06 has been added to all lengths calculated for data in Table 6.

As spawning was continuous from October 1938 until June 1939 the growth rate given in the table up to May is not representative and it appears that growth, at least in length of the larger ones, is similar in summer and winter. At the times the toheroa were observed there was no shortage of phytoplankton as even in the summer months toheroa appeared able to fill their stomachs and cease feeding in a short time after being covered by the tide. Phytoplankton, however, in the summer did not cover the beaches as it normally does in winter.

On the North Kaipara beach when these observations were made the stocks present were not great; the severe mortality of 1937-38 had

decimated the beds and no canning had been done in 1938. The remarkable growth enabled canning to be started again in the winter of 1939. This fact may be important in subsequent determinations of the growth rate as, during the summer months when phytoplankton is low, it is often impossible to find a single diatom in many litres of water on some parts of the South Kaipara, and growth must cease and toheroa lose condition, but such a state has not been observed on the North Kaipara.

In order to check the growth rate, some hundreds of toheroa were marked with a file 1 in. from the growing edge along the long axis. The choice of locality for replanting was not fortunate for recovery and only two were subsequently found. The thin growing edge of the shell was badly broken in both cases, but in 6 weeks between marking and recovery growth was about $\frac{1}{8}$ in., the damage to shell and mantle evidently being repaired in 2-3 weeks.

TABLE 6

AVERAGE SIZE OF TOHEROA AT GLINKS GAP, NORTH KAIPARA, FROM NOVEMBER 1938 TO AUGUST 1940, AND CALCULATED GROWTH PER MONTH

Date Measured	Period Considered	Age (months)	Average Size (in.)	Growth by Difference (in.)	Average Growth per Month (in.)	Average Growth per Year (in.)
			Less than			
Nov. 1938	Oct.-Nov.	*c.*$\frac{1}{2}$	0.1			
Feb. 1939	Nov.-Feb.	3	0.49	0.40	0.13	1.56
May 1939	Feb.-May	6	0.73	0.24	0.08	0.96
Aug. 1939	May-Aug.	9	1.32	0.59	0.20	2.40
Nov. 1939	Aug.-Nov.	12	1.87	0.55	0.18	2.16
Apr. 1940	Nov.-Apr.	16	2.60	0.73	0.19	2.28
Aug. 1940	Apr.-Aug.	21	3.46	0.86	0.17	2.04

Also of interest in connection with the growth is the behaviour of two toheroa less than $\frac{1}{4}$ in. kept in shallow petri dishes. The first with plenty of sand was able to burrow and died in 2 weeks. The second had only a thin layer of sand and consequently remained almost on the surface all the time. No attention was given these petri dishes, which were covered to keep out dust and left in a laboratory window. The second toheroa remained alive for 8 weeks. Growth during the time was negligible; no phytoplankton developed in the water, which under other circumstances would have produced diatoms or algae. From this it appears that under unfavourable circumstances toheroa may survive and make practically no growth for as long as 2 months; the aquarium conditions for the longest-lived specimen representing a particularly hard beach into which it could not burrow, and a very calm sea.

The length frequency data given in Appendices I-V show considerable variation. On the North Kaipara beach growth is similar over a distance of about 25 miles from Baileys to Duffs. To the south it is slower and to

the north of Baileys toheroa occurrences are irregular. The reason for the difference to the south of Duffs is the influence of water from the Kaipara Harbour, which is washed to the north. Many miles of beach bear no toheroa because of this: to the south toheroa occur on Muriwai beach, often to the South Kaipara Head.

The principal difference between the North Kaipara beach and Muriwai is in the quantity of phytoplankton, which is usually small on Muriwai. Until 1945 few commercial supplies were taken and Muriwai beach was populated with a greater or smaller number of toheroa. Ayson (1926) reported that there were few beds, but in 1937 a survey by the author proved extensive beds to be present; by 1938 these were reduced again to relatively few. Length frequency data for October 1939 are given in Appendix III.

For comparison with the North Kaipara beach, growth on Muriwai has been calculated from length frequency data over a similar period. Successful spawning is not so frequent nor are the young stages so easily found on this beach, which is remarkably featureless, so growth of small ones is not given. Although toheroa occur on this beach from the Road to South Kaipara Heads, a distance of over 30 miles, there are usually well-developed beds on only 24 miles and by far the best occur on the northern part for 15-25 miles north of the Muriwai Rocks; this is partly due to the iron sand on the southern 3-4 miles and to the northern drift.

On several occasions on this beach phytoplankton has been almost nil. The large toheroa population in December 1937 appeared to have depleted the water of plankton, but after the numbers were reduced similar very low quantities of phytoplankton occurred at times in the summer months.

Except in the vicinity of several landmarks, the finding of particular beds of toheroa on this beach presents many problems; it is obvious that toheroa here move about a lot, but whereas on other beaches the line occupied is well defined and toheroa are usually to be found in certain places, on the Muriwai occurrences are not so regular. At the landmarks Wreck and the Winch, toheroa are frequently abundant but they may be completely absent for long periods. The method employed to obtain samples was to take the car speedometer reading and record the position north of the Road entrance — by checking this with the known landmarks the position of the beds sampled could be determined with much accuracy and continuous records kept over the period of the experiment. It was found, however, that during the 2½ years of observation a complete series of measurements was not obtained from any one of the sampling points because on some occasions insufficient were obtained for a sample. An examination of the data for the Muriwai beach shows that although similarities exist in nearby beds, the uniting of samples may give misleading results because of differences in the rate of growth or time of spawning, and the irregular or poor representation of some groups in nearby areas. Only one collection of the newly settled or spat size was

made, but each sample collected contained some specimens from the high, mid, and low zones bearing toheroa, although the mid zone usually produced the greatest quantity. The samples can be said to fairly represent the beds.

TABLE 7

AVERAGE SIZE OF TOHEROA FROM 15 MILES NORTH OF MURIWAI ROCKS FROM NOVEMBER 1938 TO AUGUST 1940 AND THE CALCULATED GROWTH PER MONTH OF THOSE SPAWNED ABOUT NOVEMBER 1937

Date Measured	Period Considered	Age (months)	Average Size (in.)	Growth by Difference (in.)	Average Growth per Month	Average Growth per Year
Nov. 1938	Nov.-Nov.	13	1.39	1.39	0.11	1.3
May 1939	Nov.-May	19	1.93	0.54	0.09	1.1
Aug. 1939	May-Aug.	22	2.15	0.22	0.07	0.8
Oct. 1939	Aug.-Oct.	24	2.29	0.14	0.07	0.8
Mar. 1940	Oct.-Mar.	29	3.00	0.71	0.14	1.6
Aug. 1940	Mar.-Aug.	34	3.54	0.54	0.11	1.3

The data show that growth on Muriwai is slower than on the North Kaipara. Modes in length frequency data occurred as follows:

In December 1937 — $1\frac{3}{4}$, $2\frac{3}{4}$, $3\frac{1}{2}$ in.
October 1939 — $1\frac{1}{2}$, $2\frac{3}{8}$, 3 in.
August 1940 — $1\frac{1}{8}$, 2, $2\frac{3}{4}$, $3\frac{1}{2}$ in.

Tables 7 and 8 give the growth of two different year-classes of Muriwai toheroa, calculated as for the North Kaipara.

TABLE 8

AVERAGE SIZE OF TOHEROA FROM 25 MILES NORTH OF MURIWAI ROCKS FROM AUGUST 1939 TO AUGUST 1940 AND CALCULATED GROWTH PER MONTH OF THOSE SPAWNED ABOUT SEPTEMBER 1938

Date Measured	Period Considered	Age (months)	Average Size (in.)	Growth by Difference (in.)	Average Growth per Month	Average Growth per Year
Aug. 1939	Oct.-Aug.	11	1.00	1.00	0.09	1.1
Oct. 1939	Aug.-Oct.	13	1.41	0.41	0.20	2.4
Mar. 1940	Oct.-Mar.	18	1.90	0.49	0.09	1.1
Aug. 1940	Mar.-Aug.	23	2.25	0.35	0.07	0.8

On the Ninety-mile Beach observations were first made by the author in November 1939. A few good patches of large toheroa were present but the large beds of 5-10 years previously had disappeared. The operations of the cannery diggers had played an important part in reducing the population, but they were only indirectly responsible for the absence of successful spatting. Appendix IV shows the extremely irregular length

frequency distribution, which suggests small broods twice yearly or a very slow growth rate by other standards.

The decrease in toheroa on this beach from 1940 to 1945 suggests that some influence not affecting the more southern beaches was responsible. The principal difference from other beaches during this period was the heavy traffic during the war years, when the Ninety-mile Beach, which is a recognized highway, carried much military traffic. Vehicles usually take the half-tide level to avoid soft sand and uneven surface above and below the beds, and whenever a motor passes over beds with seepage water covering them, numbers of toheroa eject small fountains of water, not only in the position of the wheel marks but between them and on either side also, indicating that the pressure is transmitted to the partly open shells causing them to close. However, periods of scarcity have occurred in the past when there was no traffic, though it is doubtful if the beach was ever so barren as in 1946.

TABLE 9

AVERAGE LENGTH (IN.) OF TOHEROA AT EACH YEAR OF AGE FROM SHELL READINGS

Age (years)	Ninety-mile North of Mangonui Bluff	North of Waipapakaur	North Kaipara Glinks	Muriwai 15 miles North	Wellington West Coast Waitere
1	0.9	1.0	1.65	0.95	1.1
2	1.7	1.8	2.67	1.75	1.9
3	2.6	2.5	3.79	2.60	2.8
4	3.1	3.2	4.32	3.14	3.4
5	3.4	3.5	4.60	3.42	4.1
6	4.2	4.4	4.87	4.00	4.3
7				4.49	4.5
8					4.9
9					5.0

No calculation of the growth rate from length data is made here, but growth rate from shell examinations for the four main beaches is compared in Table 9.

To complete the length frequency data, Appendix V gives the sizes on the Wellington beaches. The toheroa here are larger than on any other beach and despite periods of relative abundance, the beach is sometimes without toheroa. Very strong westerlies have a beneficial effect, while periods of calm appear to affect their presence adversely. The occurrence on the beach from April to October 1940 is of interest in that the average size of those over $3\frac{1}{2}$ in. increased by more than $\frac{1}{4}$ in. in 6 months. It is not considered that the increase in size during this period represents growth, as $\frac{1}{2}$ in. per year is rather high for shellfish of this size. Other possible explanations are that the toheroa continued to migrate inshore and possibly also a northern movement along the beach occurred.

VIII. Age and Growth Rate from Shell Markings

Weymouth, McMillin, and Holmes (1925) give some conclusive results on growth in the razor clam, but no such definite findings were made from toheroa shell examinations. The irregular spawning is probably recorded in the shell markings, but there is evidence that the marks are largely seasonal; the broad band of dark growth occurs in spring or summer when the principal spawnings occur.

McMillin (1924) states that the edge of the shell of razor clams is brown in early spring and during spring or summer the shell grows away from the brown line. A possible exception occurs for spawning during early summer.

No toheroa shells were found in which the growing edge could be described as brown or dark-coloured because of a check or change in growth, but the dark zone became obvious when more growth occurred. The edge of the shell is thin and is covered during life with a thin, clear membrane which is worn off the body of the shell; it obscures the character of the edge of the shell. The zones show best in cleaned, dry shells. In small ones the zone near the hinge is clear and is followed by a broad, brown band which, however, is not always obvious in large shells. Table 9 summarizes the results of age determination in 750 shells from five locations.

As the growth rate from length frequency data showed clearly the age on the North Kaipara, this rate has to some extent been used as a guide in age determination from zones in the shell. There is no evidence of any sudden check during the first year in shells from this beach, and the brown zone representing a different type of growth is not well defined. On other beaches the brown band is often quite conspicuous in shells only 1 in. long. The age from the shells was estimated by counting a clear and dark zone for each year, starting from the clear central zone, which is opaque in large shells. On the Muriwai beach 20 per cent. of the shells collected were discarded as unreadable.

Compared with the definite data in length frequency measurements, shell markings show a marked decrease in average size at each year of age for the first 3 years on the North Kaipara, and data for other beaches are believed to be similar, viz. that the age in shell marks indicates the size in spring rather than the true growth rate per year. The longer the spawning season, the greater the shell mark determination will differ from the true growth. In the toheroa of the North Kaipara, the difference in actual growth and shell growth determination for the first year is almost $\frac{3}{4}$ in. (Table 9 and Appendix II).

Following the method of Weymouth, McMillan, and Rich (1931) the percentage surviving annually is given in Table 10. Wellington has the oldest stock and the lowest mortality rate up to the seventh year. On the North Kaipara after the second year the stock is reduced by 50 per cent. annually. High mortality is correlated with heavy surf and small area of

inshore shoal water, indicating that here a sublittoral population probably does not contribute very much to the stocks in the littoral zone. It is emphasized that the data recorded represent the condition of the stocks on each beach only at the time the collections were made. The type of stock, however, is reasonably constant from year to year on each beach, and the differences shown persist for many years. The Wellington beaches during the period 1934 to 1946 had similar stocks to those recorded for 1940, and the differences between this coast and North Auckland are rather striking. Muriwai and Ninety-mile are comparable in mortality rates, although the stocks from length frequency measurements are rather different. The North Kaipara differs in the extremely high natural mortality. It is unfortunate that where growth is so rapid the stocks are reduced so quickly, only 2 per cent. reaching 6 years of age, compared with 35 per cent. on the Wellington beaches.

TABLE 10

PERCENTAGE OF TOHEROA SURVIVING ANNUALLY FROM FOUR BEACHES

Age (years)	Ninety-mile North of Waipapakauri	North Kaipara	Muriwai	Wellington
1	100	100	100	100
2	82	68	72	88
3	39	30	51	84
4	32	15	30	80
5	23	7	21	67
6	6	2	6	35
7	4		3	12
8				4
9				2

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APPENDIX I

NORTH KAIPARA, NOVEMBER 1938 — NUMBER OF TOHEROA AT EACH ¼ IN. IN LENGTH

Length (in.)	North of Dargaville	Baileys to Chases	Chases to Maules	North of Maules	Mahutu	S. Maules to Chadwicks	Glinks	2 miles S. of Black Rocks	South of Bromiches	Duffs	¾-2½ miles S. of Tangaihi	Half way Tangaihi to Round Hill	2½ miles N. of Round Hill	About 2 miles N. of Round Hill
¾		1	2			1	1				1			1
1		7	1	3	15	2	5		2	3	13	5	1	
1¼		15	5	7	28	6	19	1	3	35	79	11	2	6
1½		15	4	4	34	2	49	2	14	114	84	9	5	12
1¾		7	15	1	26	3	19	2	16	66	75	7	7	8
2		10	15	3	26	5	7	4	7	44	40	5	3	11
2¼		10	3	1	17		8	3	17	58	62	5	4	10
2½	1	3	2		5	2	2		22	64	55	13	8	16
2¾	1	3	2		4	4	4	1	12	51	50	20	12	33
3	1	1	2	1	6	1	7	2	20	58	88	43	39	85
3¼		6	3	5	3	5	10	2	33	52	96	50	23	74
3½	1	14	3	15	3	15	15	5	63	37	59	41	15	28
3¾	1	13	6	14	9	10	17	4	65	16	17	24	6	14
4	2	11	8	9	14	7	9	4	42	1	7	9	2	2
4¼	3	6	1		3	3	8	6	31	1	1	6	1	1
4½	1	4	2	2		2	1	5	7		2	2	1	
4¾	1	6		1		1			3			1		
5				1					1					

APPENDIX II

NORTH KAIPARA, GLINKS GAP — NUMBER OF TOHEROA AT EACH $\frac{1}{8}$ IN. LENGTH OF THE 1938-39 BROOD OBSERVED FROM NOVEMBER 1938 TO AUGUST 1940

Length (in.)	1938 Nov.	1939 Feb.	1939 May	1939 Aug.	1939 Nov.	1940 Mar.	1940 Aug.
Less than $\frac{1}{8}$	83						
$\frac{1}{8}$	41	7	2				
$\frac{1}{4}$		20	8				
$\frac{3}{8}$		68	32				
$\frac{1}{2}$		68	87	3			
$\frac{5}{8}$		47	191	15			
$\frac{3}{4}$		22	190	43			
$\frac{7}{8}$		9	183	72			
1		2	144	90			
$1\frac{1}{8}$			97	123			
$1\frac{1}{4}$			53	149	1		
$1\frac{3}{8}$			26	123	1		
$1\frac{1}{2}$			8	98	5		
$1\frac{5}{8}$			5	98	7		
$1\frac{3}{4}$				77	15	1	
$1\frac{7}{8}$				62	12	1	
2				29	21	1	
$2\frac{1}{8}$				15	9	3	
$2\frac{1}{4}$				3	3	3	
$2\frac{3}{8}$					1	5	
$2\frac{1}{2}$						9	
$2\frac{5}{8}$						13	
$2\frac{3}{4}$						17	1
$2\frac{7}{8}$						9	1
3						6	3
$3\frac{1}{8}$						2	6
$3\frac{1}{4}$							3
$3\frac{3}{8}$							11
$3\frac{1}{2}$							10
$3\frac{5}{8}$							13
$3\frac{3}{4}$							3

APPENDIX III

MURIWAI, OCTOBER 1939 – NUMBER OF TOHEROA AT EACH $\frac{1}{8}$ IN. IN LENGTH

Length (in.)	3.5 miles N. of Muriwai	5.6 miles N. of Muriwai	9.5 miles N. of Muriwai	12.7 miles N. of Muriwai	16.1 miles N. of Muriwai	21.5 miles N. of Muriwai	22.7 miles N. of Muriwai Top	22.7 miles N. of Muriwai Bottom	24.9 miles N. of Muriwai	25.7 Miles N. of Muriwai	30.0 miles N. of Muriwai
$\frac{3}{4}$								1			
$\frac{7}{8}$					1		4			2	
1		1	2	1	5	1	9	2	1	4	
$1\frac{1}{8}$	2		2	5	2	1	5		1	4	
$1\frac{1}{4}$	2	3		11	2	5	7	3		7	
$1\frac{3}{8}$	1		4	12	2	1	14	4	1	5	
$1\frac{1}{2}$	4	2	1	16	7	4	22	6	1	8	
$1\frac{5}{8}$	1		2	5	3	3	7	5	2	12	
$1\frac{3}{4}$		1	3	7	1		7	6	2	12	
$1\frac{7}{8}$			1	2		2	6	4	3	4	1
2	1	6	3	5	1	5	4	4	3	17	
$2\frac{1}{8}$	3	14	9	7	1	5	1	4	4	23	3
$2\frac{1}{4}$	12	19	14	3		17	1	4	10	31	10
$2\frac{3}{8}$	17	12	22	8	1	11	1	1	7	19	16
$2\frac{1}{2}$	17	14	22	3	2	10			7	17	13
$2\frac{5}{8}$	5	10	13	4	3	5		2	3	8	13
$2\frac{3}{4}$	8	7	9	6	1	1		1	4	6	14
$2\frac{7}{8}$	1	4	10	1		5			7	1	8
3	1	4	13	5		5		1	19	2	6
$3\frac{1}{8}$	2	5	8	3	1	12			15	3	4
$3\frac{1}{4}$	3	7	8	5	3	12	1	2	26	1	5
$3\frac{3}{8}$	3	6	11	6	2	12	1	14	17	2	5
$3\frac{1}{2}$	1	5	7	3	5	19	3	14	14	2	2
$3\frac{5}{8}$	1	2	7	7	14	9	5	14	11	1	1
$3\frac{3}{4}$			3	1	19	1	2	9	5	1	4
$3\frac{7}{8}$			2	6	11	1	3	8	1		4
4			2	1	17	1	1	2			3
$4\frac{1}{8}$				1	6	1	2	1			1
$4\frac{1}{4}$				1	4		1				
$4\frac{1}{2}$					3						
$4\frac{3}{8}$					2						1

APPENDIX IV

NINETY-MILE, NOVEMBER 1939 – NUMBER OF TOHEROA AT EACH $\frac{1}{8}$ IN. IN LENGTH

Length (in.)	Scott's Pt.	6.0 miles N. of Mangonui Bluff	*c.* 4 miles N. of Mangonui Bluff	2.8 miles N. of Mangonui Bluff	*c.* 1.0 miles N. of Mangonui Bluff	Just N. of Mangonui Bluff	30.0 miles N. of Waipapakauri	27.0 miles N. of Waipapakauri	26.0 miles N. of Waipapakauri	25.5 miles N. of Waipapakauri	25.2 miles N. of Waipapakauri	23.0 miles N. of Waipapakauri	19.7 miles N. of Waipapakauri	18.7 miles N. of Waipapakauri	17.0 miles N. of Waipapakauri	11.15 miles N. of Waipapakauri	3.11 miles N. of Waipapakauri
$\frac{1}{4}$		4															
$\frac{3}{8}$		12															
$\frac{1}{2}$		14	2				1	1									
$\frac{5}{8}$		4			1		1				2			1			
$\frac{3}{4}$	1	9		2				1	1		2			1			
$\frac{7}{8}$	4	4	1	3	3		1				4						
1	6	6	2		4		5	4	1		4		1	5			
$1\frac{1}{8}$	11	14	3		8		2	9	1	2	7		2	6			
$1\frac{1}{4}$	7	15	7	3	6		4	8	1	2	10	1		7			
$1\frac{3}{8}$	7	11	2	5	8	2		4	2	5	5	2	5	7			
$1\frac{1}{2}$	5	8	3	6	11			1	2	10	5	1	5	14	2	1	
$1\frac{5}{8}$	5	3	5	4	9		2	6	2	4	4	1	3	13	1	1	
$1\frac{3}{4}$	5	2	3	4	5	2	4	4	6	3	6	6	4	13		5	
$1\frac{7}{8}$	7	2	7	3	14	1	3	5	4	3		5	5	14	1	5	3
2	1	3	6	8	11	4	7	7	10	10	4	6	4	11		7	7
$2\frac{1}{8}$	2	5	5	2	7	6	3	10	6	3	11	4	1	6		9	9
$2\frac{1}{4}$	4	4	8	21	11	10	14	9	7	6	13	6	12	15	1	18	18
$2\frac{3}{8}$	5	3	5	13	4	12	6	4	3	3	9	5	16	4	1	6	15
$2\frac{1}{2}$	5	1	7	13	12	15	5	3	1	5	3	11	15	14		8	7
$2\frac{5}{8}$	4	1	5	15	4	10	8	4	1	3	2	14	17	14	1	3	4
$2\frac{3}{4}$	5	3	7	14	4	12	2	3	3	4	1	14	27	20	1	4	9
$2\frac{7}{8}$	3	11	3	5	2	22	4		1	2	3	14	21	25			7
3	5	7	1	9	4	18	1	3	2	4	4	5	10	16		2	12
$3\frac{1}{8}$	7	8		12	4	16	4	10	1	6	2	2	3	9	1	3	5
$3\frac{1}{4}$	11	1	1	13	6	23	3	11		6	2	1	2	4	2	8	12
$3\frac{3}{8}$	5	1		24	3	15	1	2	2	3	1			3		10	16
$3\frac{1}{2}$	4	1		15	1	29	2	2		6	3		1	1	1	15	20
$3\frac{5}{8}$	2	1		8	2	16	9	1	1	2				1	2	20	16
$3\frac{3}{4}$	1			2		17	9	2	2	1	1				3	14	26
$3\frac{7}{8}$						6	12				1		1		5	12	7
4						5	22						1	1	6	10	7
$4\frac{1}{8}$						1	9								2	2	1
$4\frac{1}{4}$							8							1	3	5	
$4\frac{3}{8}$							2										
$4\frac{1}{2}$							2								1		
$4\frac{5}{8}$							1										

APPENDIX V

WELLINGTON WEST COAST, MANAWATU TO WAIKANAE – NUMBER OF TOHEROA AT EACH $\frac{1}{8}$ IN. LENGTH

	April 1940				October 1940					
Length (in.)	Manawatu to Waitere	Waitere to Hokio	Hokio to Ohau	Ohau to Otaki	Manawatu to Waitere	Waitere to Hokio	Hokio to Wiwiri	Wiwiri to Ohau	Ohau to Waikawa	Ohau to Waikanae
1	1									
1⅛	2			1						
1¼				2			1			
1⅜				2		2				
1½				1	1					
1⅝					1					
1¾					1		2			
1⅞	2					1				
2					1	2				
2⅛	1					3	1	1		
2¼	2						2	1		
2⅜	1	4				1	2			
2½	2	2								
2⅝	1	2								
2¾		1		2	1	1				
2⅞			1		1	1				
3	1				1		1			
3⅛	1					2				
3¼					1					
3⅜	4	4	1		2	1				
3½	5	8				3				1
3⅝	6	9	2	1	1			1		
3¾	16	11	3	4	2	2				1
3⅞	12	23	11	3	2	1	1	3	1	
4	29	22	13	7	4	2			1	
4⅛	21	34	13	16	17	12	3	1		12
4¼	20	23	25	17	11	8	7	2	2	13
4⅜	14	20	21	25	13	12	11	3	3	13
4½	8	11	13	19	26	18	16	3	2	33
4⅝	3	5	10	13	26	19	23	15	10	28
4¾	1	2	4	8	17	12	20	19	9	25
4⅞	2	1	2	4	4	9	11	12	6	7
5		2	4	1	4	3	5	21	2	5
5⅛			3			2	2	10		
5¼							2	5		1
5⅜					1		2	3		
5½								2		
5⅝								1		

OBSERVATIONS ON THE MOLECULAR STRUCTURE OF BYSSUS FIBRES

By E. H. Mercer*

(*Manuscript received January* 31, 1952)

Summary

Byssus fibres from *Mytilus planulatus* Lamk. and from *Subitopinna madida* Reeve were examined by X-ray diffraction and by electron microscopy. The birefringence of the threads was also measured. The results show that *Mytilus* threads consist of collagen but that the threads of *Subitopinna* are very poorly oriented and could not definitely be identified with collagen.

I. Introduction

Many bivalves secrete a bundle of protein fibres, called the byssus, which they use to fasten themselves to supports or to assist movement. The threads have been used as a textile fibre since early times†, and have sometimes been called "mussel silk" (Centola 1936). Several authors have examined the threads by means of X-rays in an attempt to identify the class of fibrous proteins to which they belong. This information is of interest in the attempt to determine the distribution of the several molecular types of fibrous protein in nature, a subject that has just been reviewed by Rudall (1950). It is remarkable that in their basic small-scale molecular framework, which is revealed in the wide-angle X-ray pattern, the fibrous proteins appear to form only three classes: the α-proteins (type example, wool keratin), the β-protein (type, silk or feather keratin), and the collagens (type, rat tail tendon). Since the molecular structure derives from the mode of synthesis of the protein, it seems that there must be some profound significance in the limited number of types (Astbury 1947; Rudall 1950).

Centola (1936) believed the byssus was a kind of silk related to the silks secreted by insect larvae and spiders. His X-ray patterns were difficult to identify and showed mixed characteristics of both keratin and silk fibroin. Trogus and Hess (1933) in their survey of various silks reproduce a very sharp ring pattern obtained from the byssus of *Pinna* which did not resemble that of any known protein. Brown (1947) claimed that the fibres were collagen hardened in a manner similar to that occurring in the insect cuticle. The patterns obtained in the present study establish beyond doubt that the threads of *Mytilus* consist of collagen although there are some additional features, whereas those of *Pinna,* as found by earlier authors, are difficult to identify.

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† See 1 Chronicles iv.21, xv.27 (Hebrew version).

II. Experimental

(*a*) *Material*

The byssus used was obtained from specimens of the common rock mussel of the southern Australian coast (*Mytilus planulatus* Lamk.) and from a specimen of *Subitopinna madida* Reeve from Queensland, which resembles the *Pinna nobilis* Linn. of the Mediterranean used by previous authors.

The byssus consists of two distinct parts (Fig. 1(*a*)): the stem *A* secreted by the byssus pit and the threads *B* secreted by the groove of the foot (Fig. 1(*b*)). The stem emerges from the byssus pit and is unattached distally; the threads are attached at one end to the stem and at the other end to an attachment disc fastened to the support. A full account of these structures is given by White (1937). The whole byssus was removed from the living animal by pulling and was cleaned by standing in distilled water for several days and then extracted in a soxhlet using petroleum ether b.p. 60°-80°C.

(*b*) *X-ray Examination*

Diffraction patterns were obtained using filtered nickel radiation and a flat film. The specimen-film distance was 4 cm. In the *Mytilus* specimens various positions along the threads (1, 2, 3 in Fig. 1(*a*)) and the stem at 4 were X-rayed with the beam normal to the fibre axis. There was no opportunity to attempt to examine the low-angle pattern although the vertebrate collagens give very characteristic reflections in this region (see below).

Well-oriented, well-defined patterns such as that reproduced in Plate 1, were given by the most distal portions of the threads of *Mytilus* (positions 1 and 2, Fig. 1(*a*)). The pattern in Plate 1 is typical of a collagen and may be compared with those reproduced by Astbury (1940, 1947). Particularly diagnostic is the meridional arc at 2.8 Å. and the equatorial spots at 10.4 Å. An anomalous feature is the sharp ring centred at 4.2 Å.

The photograph from the byssus stem (position 4) was diffuse and only just identifiable as from collagen. Similarly the pattern from the proximal portion of the threads (position 3) was diffuse and poorly oriented. None of the photographs was improved by stretching the threads 70 per cent.

The pattern obtained from the byssus of *Subitopinna* was, in contrast to the above, diffuse, very poorly oriented, and not identifiable with certainty with that of collagen. It was quite different from the pattern of sharp rings described by Trogus and Hess (1933) and resembled more that described by Centola (1936). The only oriented features were meridonial arcs at about 4.2 Å. which are not sufficient to permit of identification. Stretching the threads 50 per cent. did not improve the photograph. It is clear from this that the failure of certain authors to identify the threads is due to the very different degree of orientation shown

by the threads of various species, and to their having studied the threads from *Pinna,* which, although the finest and most attractive fibres, are the least well crystallized and oriented.

The very low birefringence (*c.* 0.002) of the *Pinna* threads accords with the X-ray finding.

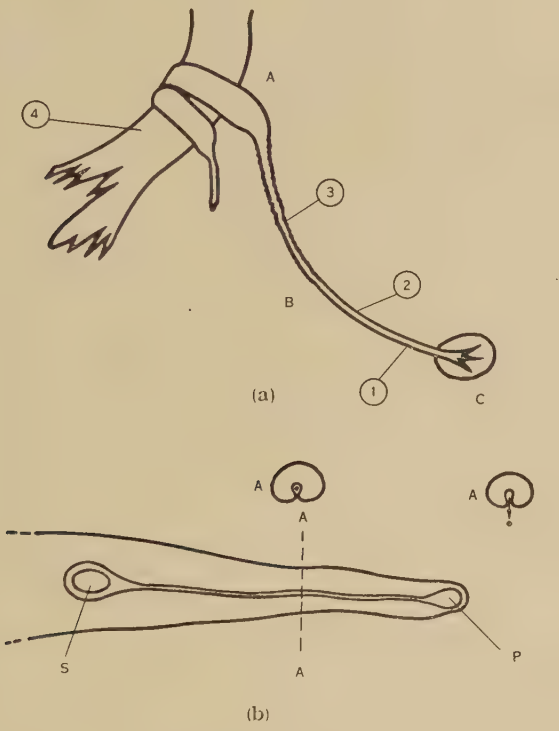

Fig. 1.—(*a*) Relation of the byssus stem and a thread of the byssus of *Mytilus.* At *A* is the collar-like attachment to the stem and at *C* the attachment disc fastening the thread to its support. The numbers refer to the positions from which X-ray photographs were obtained. (*b*) The extensible tongue-like foot showing the stem, *S,* penetrating the base of the foot, the groove, and the sucker, *P,* which secretes the attachment disc. The thread is formed within the groove and is released by the opening of the groove.

(*c*) *Extensibility of the Threads*

This question is of particular interest because it is known that vertebrate collagen shows only a small extensibility (<10 per cent.). This property is thought to be a direct consequence of an inextensible form of molecular framework (Astbury 1940). Byssus threads are on the contrary

very extensible. The degree of this extensibility (under the same conditions in water) varies somewhat from fibre to fibre but is commonly between 70 and 100 per cent. Older and darker threads are more brittle as a rule, but some fresh threads were found to break at *c.* 50 per cent. extension. This apparently anomalous behaviour was further investigated.

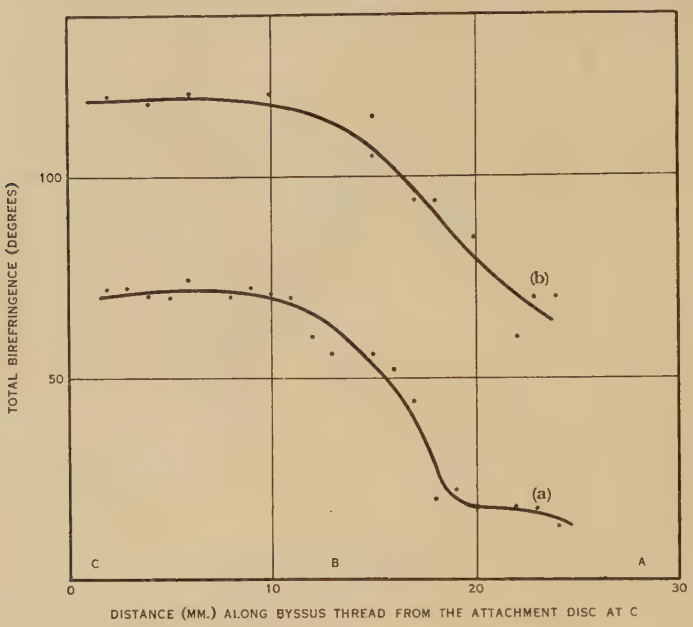

Fig. 2.—Curves relating total phase difference (total birefringence) angle measured on Sénarmont compensator and distance along byssus thread from the attachment disc (*Mytilus*).

(*a*) Original thread. Notice the lower birefringence in the portion of the thread nearest the stem (*AB* 15-25 mm. from disc).

(*b*) The same thread after stretching 50 per cent. To enable a direct comparison to be made with positions along the original thread the length scale is two-thirds of that in (*a*).

Examination of an entire thread shows that adjacent to the stem attachment (Fig. 1(*a*)) the surface is wrinkled. When marks were placed on a thread it was noted that the greater part of the increase in length during stretching occurred in this region. As mentioned above the X-ray pattern of this portion was less well defined and the birefringence lower. These observations point to an inferior degree of orientation in this region. However, a 70 per cent. extension was not found to improve the orientation in this region as shown by X-rays.

An alternative method of studying changes in the degree of orientation is by measurement of the birefringence. Byssus threads of *Mytilus* are

strongly birefringent. Figure 2, curve (*a*), shows the birefringence at various points along a fibre from the attachment disc. The lower value in the region *AB* is apparent. A marked rise occurs in this region on stretching (curve (*b*)). This probably means that extension in this region is effected not by molecular extension, but by an improved orientation of poorly aligned material. The failure to demonstrate better orientation by X-rays may mean that the formation of well-defined crystallites capable of diffracting X-rays is somehow hindered. A possible source of hindrance would be intermolecular cross-linking effected by the hardening reaction. In contrast to those of *Mytilus* the threads of *Subitopinna* have a very low double refraction.

(*d*) *Electron Microscopy*

The vertebrate collagens are characterized by (i) their wide-angle X-ray pattern and (ii) by the very characteristic fine structure of striations having a major period of 650 Å. readily detected either by electron microscopy or by low-angle X-ray diffraction (Schmitt 1944).

Both stem and threads were examined in the electron microscope for the presence of the larger structures. The material, being too hardened to break down mechanically, was macerated for some weeks in a peptic digest (0.05 per cent. pepsin (Difco), pH 1-2, 40°C.) and fragmented in a Waring Blendor. The finer fragments were examined in the electron microscope. Neither the stem nor the threads appeared to possess the familiar cross-striations.

III. Discussion — Formation of Byssus

Judging from X-ray photographs the byssus is formed from a protein of the collagen class. The orientation of the protein is variable in the threads but is usually good near the attachment disc. The byssus body is also fibrous although poorly oriented. Unfortunately no modern analysis of the amino-acid composition is available to enable a comparison to be made with other collagens. The familiar fine structure of transverse striations shown by vertebrate collagen was not detected. This failure might have been due to an experimental factor, e.g. difficulty of staining the hardened protein. Reed and Rudall (1948) have examined another invertebrate collagen, the earthworm cuticle, by electron microscopy and also failed to find the cross-striations. It is therefore not unlikely that some collagens may lack the familiar macromolecular structure.

The formation of the threads of byssus is very interesting and has been described by several authors (Williamson 1906; Field 1922; White 1937). It provides another example of a fibrous protein formed initially as a soluble glandular product and subsequently secreted, transformed into a fibre, and moulded into shape by mechanical means. The thread is formed in the groove, which extends along the ventral surface of the tongue-like foot as shown in Figure 1(*b*). The foot is extended and in

this position the lips of the groove are compressed together, converting the groove into a tube (Fig. 1(*b*) at *A*). The tip is placed against a firm surface and the small attachment plate is secreted. The groove meantime has filled with the secretion from the white gland of the foot. When this has hardened the foot is relaxed, the groove opens and the finished thread is released. At first white, the thread turns slowly yellow and then brown. This seems to be due to a chemical change related to the hardening of the insect cuticle as suggested by Brown (1947).

The secretion from the white gland may be examined by slitting the edge of the groove. It forms a clear, sticky fluid easily drawn into threads, which soon harden. Some preliminary observations were made of the fibre-forming properties of the glandular extract dissolved in water. When examined in the electron microscope the dried extract was found to consist of a mixture of fibrous and particulate material, which may be evidence of a partial transformation of the soluble secretion into the fibrous mode as occurs with certain other fibre-forming proteins. This type of experiment needs to be developed further. As the secretion is simply poured from minute ducts opening transversely into the groove, it seems unlikely that it would possess at first the longitudinal orientation displayed by the finished thread. This probably arises from the extension of the unhardened thread due to the extension of the foot. The better orientation of the thread adjacent to the disc in *Mytilus* could be caused by the greater extension of the tip and the different degrees of orientation between threads be due to different foot extensions.

IV. Acknowledgments

The author wishes to thank Miss J. H. Macpherson of the National Museum, Melbourne, for her help in obtaining specimens for this study; and Dr. A. B. Wardrop of the Division of Forest Products, C.S.I.R.O., for the use of diffraction equipment.

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MOLECULAR STRUCTURE OF BYSSUS FIBRES

X-ray pattern yielded by the distal portion of the byssus threads of *Mytilus*. Ni radiation: film-to-specimen distance 4 cm. A collagen-type pattern.

THE ASCIDIANS OF AUSTRALIA

I. STOLIDOBRANCHIATA LAHILLE AND PHLEBOBRANCHIATA LAHILLE

By Patricia Kott*

(*Manuscript received December 6, 1951*)

Summary

An account is given of a collection of 85 species of simple ascidians from all parts of the Australian coast, including descriptions of 23 species new to science. Comprehensive keys for all species already described from the Australasian area accompany the account of each genus. There is a short discussion on the distribution of simple ascidians in Australia; and the Baudinian region, a new zoogeographic marine region in south Western Australia is proposed.

I. Introduction

An account of some sedentary ascidians of these coasts was published by Professor W. A. Herdman (1899). Since then there have been many advances in the knowledge of the group, amended classification, and increasing necessity for more detailed information on each species. However, despite the prominence of the group in Australian waters there have been no further accounts published (except records of a few specimens from the Barrier Reef Expedition) for the east coast. Michaelsen and Hartmeyer (1928) published an account of the group in Western Australia.

The original collection on which this present work is based was in the hands of Dr. H. Thompson, Chief of the Division of Fisheries, C.S.I.R.O., Cronulla, N.S.W., and was augmented by collecting along the Western Australian, South Australian, Victorian, New South Wales, and Queensland coasts during 1948-49. In addition, all of the Australian Museum collection has been examined, including Herdman's type specimens. In many instances Professor Herdman's descriptions have needed augmentation regarding certain characteristic features, especially alimentary canal and gonads, which he had not described. Further specimens, part of a collection made by J. A. Tubb from South Australia and Victoria, have also been studied in compiling the following descriptions.

Twenty-three new species are recorded: *Styela lobata*, sp. nov.; *S. ramificata*, sp. nov.; *S. pavementis*, sp. nov.; *S. rectangularis*, sp. nov.; *S. barbaris*, sp. nov.; *Polycarpa capricornia*, sp. nov.; *P. intestinata*, sp. nov.; *P. unilineata*, sp. nov.; *Polyandrocarpa triggiensis*, sp. nov.; *P. australiensis*, sp. nov.; *Amphicarpa elongata*, sp. nov.; *Pyura leeuwinia*, sp. nov.; *P. plicata*, sp. nov.; *Microcosmus stolonifera*, sp. nov.; *M. nichollsi*, sp. nov.; *Molgula janis*, sp. nov.; *M. minuta*, sp. nov.; *M. batemani*, sp. nov.; *M.*

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medusa, sp. nov.; *Ascidia aclara*, sp. nov.; *A. thompsoni*, sp. nov.; *Ecteinascidia flora*, sp. nov.; and *Perophora multistigmata*, sp. nov.

Two new varieties are also recorded: *Pyura momus* (Savigny) var. *curvata*, var. nov.; and *P. australis* (Quoy and Gaimard) var. *parvispinatis*, var. nov.

The following species are recorded from this area for the first time: *Astereocarpa cerea* Sluiter; *Polycarpa obtecta* Traustedt; *P. moebii* Michaelsen; *P. obscura* Heller; *P. thelypanes* (Sluiter); *Pyura subuculata* (Sluiter); *P. jacatrensis* (Sluiter); *Ascidia aspersa* Müller; *A. nigra* Herdman; *Perophora bermudiensis* Berrill; and *Rhodosoma turcicum* Savigny.

II. Classification

Keys have been prepared to assist in identification; these cover most described forms from tropical and subtropical waters, except where descriptions are inadequate. References to most recent records are given, in each case, in the keys. The general outline of the classification used follows that given by Huus (1937) in Handbuch der Zoologie. Species in the key marked by an asterisk indicate those described here.

It has become obvious, during the study of this collection, that the classification as it stands does not agree with many relationships within the group. The position cannot be markedly improved by study of the adult forms, but it is hoped that a comprehensive study of developmental forms may at some future date facilitate further work on the taxonomy of the group.

Conventions followed in descriptions.—Length—from the most posterior part of the body to the most anterior (this includes the external siphons where they extend beyond the anterior part of the body proper).

Breadth—the widest part of the body, dorsoventrally.

First branchial fold—this is the most dorsal fold.

Order PLEUROGONA (Huus)

Sub-order STOLIDOBRANCHIATA (Lahille)

Solitary or colonial ascidians; branchial sac with numerous stigmata, longitudinal bars, and (usually) folds; apertures either unlobed or with 4 or 6 simple lobes on branchial aperture and 4 on atrial aperture.

Family Styelidae Sluiter 1895

Colonial or solitary. Sac has never more than 4 folds on each side. *Stigmata straight.* Dorsal lamina smooth. *Tentacles simple.* Stomach obviously delimited from the rest of the alimentary canal. Liver never lobed.

Family Pyuridae Hartmeyer 1908

Solitary; sac has usually more than 4 folds on each side. *Stigmata*

straight. Dorsal lamina smooth or with languets. *Tentacles compound;* stomach obviously delimited from the rest of the alimentary canal; liver lobed.

Family MOLGULIDAE Lacaze-Duthiers 1877

Solitary; with or without folds; *Stigmata usually curved,* forming spirals or grouped spirally; dorsal lamina smooth-edged or toothed. Stomach not obviously delimited; liver lobed. *Tentacles compound; simple renal sac* present.

Family STYELIDAE

Included here in this family are all genera of subfamilies Polyzoinae Hartmeyer 1903 and Botryllinae Adams 1858. Hartmeyer (1923) suggests the union of the two groups—Polyzoinae and Styelinae—on the grounds that pallial budding is not universal in colonial Polyzoinae. Michaelsen (1930) advocates their separation, suggesting that similarities are due to convergence; and that there are constant differences in the 2-lipped condition of the anal border and the small number of folds (less than 4) in the branchial sac—both common in Polyzoinae and exceptional in Styelinae.

It has been observed, however, that occurrence and non-occurrence of these characters in the respective groups is by no means constant; *Astereocarpa cerea* Sluiter has 2 definite lips on the anal border, while specimens of *Stolonica australis* Mich. examined have indentations around the anal border and *Oculinaria australis* Gray has 3 well-marked anal lobes. Both *Polyandrocarpa lapidosa* Herd. and *Oculinaria australis* Gray have 4 folds on either side of the branchial sac. The arrangement and nature of the gonads in the former are exactly similar to some typical styelids and differ only from the latter in their absence from the right-hand side of the body.

Further, Berrill (1948), discussing pallial budding in Polyzoinae, mentions the fact that it is common only to the latter and to Botryllidae, and therefore these two should not be separated merely by presence of common cloacal openings. Reduction in the number of longitudinal bars in the branchial sac is a feature common to many other genera of the family Styelidae, and therefore cannot be used as a distinguishing feature.

From the above arguments, therefore, there is no constant feature of sufficient importance that can be used to distinguish each of these subfamilies and they are here grouped into the one family according to the key below.

Berrill (1948) considers *Polyandrocarpa* as the basic type, with 4 branchial folds and many gonads; larger solitary forms arise from it by loss of photolith and pallial budding; other Polyzoinae retain these, but differentiation here may be correlated with specialization and changes resulting from reduced size, due perhaps to crowding by buds, and consequent reduction in branchial sac and gonads.

Polycarpa, Cnemidocarpa, and *Styela* are all very closely allied genera, of which intermediate forms have been described. *Styela* has been differentiated from *Cnemidocarpa* by the dendritic nature of the testes. Van Name (1945) refers to "numerous, small testes attached to the body wall near to (alongside or around the end of) the ovary but separately from it", in his definition of *Styela.* Specimens of *S. plicata* Les. were minutely examined and the testes ducts from the follicles lie on the ovary as in *Cnemidocarpa* and *Polycarpa.* The testicular follicles in *Cnemidocarpa* are often hidden underneath the ovary but the ducts still come around to the surface of the ovary and open above the oviduct. Therefore the compact appearance of the testes in *Cnemidocarpa,* as opposed to *Styela,* may be due to a more dense distribution of testes, their development in a different plane, or their disposition around the ovary. The dendritic appearance in some cases may also be due to maturity (*S. etheridgii* Herd.).

Polycarpa has been differentiated from *Cnemidocarpa* and *Styela* by the larger number of gonads present, "shorter, ovate, or rounded" (Van Name 1945). Species with numbers of gonads in several longitudinal series have been ascribed to *Cnemidocarpa* owing to the length of these gonads (*C. polyphlebodes* Hart.) ; but numbers of *Polycarpa* have gonads tending to that condition, if not definitely elongate. So that here too the definition of *Cnemidocarpa* Huntsman is confused.

Nor is the condition of the atrial velum in *Cnemidocarpa* unique; it is present in some *Styela* and in *Polycarpa* as in *P. pomaria* (Sav.) and *P. fibrosa* (Stimps.) found in European waters.

Further evidence is needed before the genus *Cnemidocarpa* as defined by Huntsman is dispensed with, but in the following keys, for practical convenience, species described in the past as *Cnemidocarpa* are regarded as intermediate forms between *Styela* Fleming and *Polycarpa* Heller, and have been distributed between these 2 genera according to their gonad structure.

Hartmeyer (1919, p. 94) has discussed the relationships of *Distomus diptychos* Hart. with other related genera, and Michaelsen (1922) has erected the genus *Amphicarpa* to accommodate specimens with scattered gonads of both sexes on either side of the body. It would seem, however, that the similarity of other characters in the several genera, and the general variability in arrangement of the gonads observed in specimens in this collection, make a subdivision into genera, on the grounds only of arrangement of gonads, an unwarranted one; and it may be possible, when further species have been examined, to place all the members of this group in the genus *Distomus* Gaertner. *Amphicarpa diptychos* Hart. shows, in the presence of gonads of both sexes on both sides of the body, a strong relationship with *S. australis* Mich.; but the branchial sac and alimentary canal have a greater tendency toward the North Atlantic and

Mediterranean species of *Distomus*. The latter, however, are more allied to *S. australis* in the number of bars in the branchial sac.

All these factors seem to indicate, as stated above, that the division into three genera is impracticable.

Concerning related genera *Botryllus* and *Botrylloides,* Arnbäck (1925*b*) has surveyed the history of generic names concerned here and as a result of her work on the development of the egg (Arnbäck 1922), makes distinctions, as did Michaelsen (1922), between a *schlosseri* group and a *leachii* group.

Michaelsen based his distinctions on what he considered were the constant differences in the stomach, gonads, and the arrangement of the zooids in the colony. There is, however, no clearly defined line between the two; it is pointed out that *Botryllus aureus* Sars., as described by Michaelsen (1922) from boreal regions, is identical with *B. schlosseri* f. *typica;* Hartmeyer described what is presumably the same species as *B. schlosseri* f. *aurea,* and yet Arnbäck (1925*a*) finds more affinities with the *leachii* group in these forms (i.e. in the presence of brood pouch, arrangement of zooids) even though the stomach is more as in the *schlosseri* form.

The presence or absence of brood pouch is therefore used here as the distinguishing feature between the two genera. Van Name's distinction, based on the relative position of the testes and ovaries, was found to be too variable and changed relatively as the zooid developed. Colours, as pointed out by Bancroft (1903) are of no value whatsoever as specific characters, and vary with age and with the individual and its environment. Berrill (1950) suggests that light affects the colour of individuals and that there is some correlation between the colours of the colonies and the depths at which they are found; from observations on the colonies in this collection, and in the field, no correlation between the light incident on the animals, nor with their depth, could be made; this agrees with the findings of Bancroft.

Key to Genera of Styelidae

1. With pallial budding 2
   No pallial budding 13
2. Folds in the branchial sac 3
   No folds in the branchial sac 7
3. Four branchial folds 4
   Less than 4 branchial folds 5
4. Gonads on one side of the body only . . . . . *Oculinaria* Gray
   Gonads on both sides of the body . . . . . *Polyandrocarpa* Michaelsen
5. Two or 3 branchial folds 6
   One branchial fold . . . . . *Syncarpa* Redikorzev
6. One gonad . . . . . *Gynandrocarpa* Michaelsen
   Many gonads . *Distomus* Gaertner (including *Stolonica* Lacaze-Duthiers & Delage)

7. Hermaphrodite gonads 8
   Unisexual gonads . . . . . *Alloeocarpa* Michaelsen
8. Many polycarps . . . . . *Polyzoa* Lesson, *Dictyostyela* Oka
   Few polycarps 9
9. Four internal longitudinal bars on each side 10
   Three internal longitudinal bars on each side 11
10. One hermaphrodite gonad on each side . . . . . *Symplegma* Herdman
    One hermaphrodite gonad on left . . . . . *Kukenthalia* Hartmeyer
11. Ovary surrounded by testes . . . . . *Botryllocarpa* Hartmeyer
    Ovary above or below testes 12
12. Egg develops in brood pouch . . . . . *Botrylloides* Edwards
    Egg develops in peribranchial cavity . . . . . *Botryllus* Gaertner
13. Gonads on both sides of the body 14
    Gonads on the right side of the body only . . . . . *Dendrodoa* MacLeay
14. With branchial folds 15
    Without branchial folds . . . . . *Pelonaia* Goodsir and Forbes
15. Gonoducts always open dorsally 16
    Some gonoducts always directed ventrally . . . . . *Astereocarpa* Brewin
16. Elongate gonads with single series of ducts opening toward atriopore in one longitudinal row about the atriopore . . . . . *Styela* Fleming
    Shorter and more numerous gonads with individual ducts, opening dorsally, in more than one row, or scattered over the body wall; or arranged in a single row lying ventrally beneath the endostyle . . . . . *Polycarpa* Heller

Genus STYELA Fleming

Key to Species of the Genus Styela

1. Gonads much branched or ramifying, or both 2
   Gonads not much branched or ramifying 3
2. External siphons present . . . . . *S. whiteleggii* Herd.*
   Apertures sessile . . . . . *S. ramificata,* sp. nov.*
3. Dorsal lamina with languets . . . . . *S. bythia* Herd. (Herd. 1882)
   Dorsal lamina without languets 4
4. Folds scarcely project into branchial cavity 5
   Folds well defined, projecting into branchial cavity 6
5. Dorsal lamina wide, ribbed, toothed . . . . . *S. flava* Herd. (Herd. 1882)
   Dorsal lamina narrow, plain-edged (no significant distinctions have been recorded between these two species) . . . . . *S. oblonga* Herd. (Herd. 1882)
   S. glans Herd. (Herd. 1882)
6. More than 6 gonads on each side 7
   Not more than 6 gonads on each side 8
7. Inconspicuous dorsal tubercle . . . . . *S. ascidioides* Herd. (Herd. 1906)
   Openings of dorsal tubercle broken up and scattered . *S. cylindrica* Sluit. (Sluit. 1904)
8. Ventral folds indistinct . . . . . *S. squamosa* Herd. (Herd. 1882)
   All folds distinct 9
9. Twenty to 30 longitudinal bars between folds 10
   One to 12 longitudinal bars between folds 12
10. Alimentary canal extends anteriorly . . . . . *C. sigma* Hart. (Hart. 1906)
    Alimentary canal does not extend anteriorly 11
11. Two gonads on each side . . . . . *C. sedata* Sluit. (Sluit. 1904)
    Four gonads on each side . . . . . *C. meandria* Sluit. (Sluit. 1904)

12. Stigmata more than 10 in some or all meshes 13
Stigmata rarely more than 10 in each mesh 18

13. Gonads not straight, very curved; long rectangular stomach .. *S. lobata*, sp. nov.*
Gonads usually or almost straight; oval stomach 14

14. Test thin .. .. *S. lactea* Herd. (Herd. 1882)
Test thick 15

15. Stomach long, rectangular 16
Stomach oval or spindle-shaped, short 17

16. Testes lie on top of ovary .. .. *S. stolonifera* Herd.* (Herd. 1899)
Testes lie on body wall around ovary .. .. *S. rectangularis*, sp. nov.*

17. Ten to 14 stigmata in each mesh .. .. *C. irma* Hart.* (Mich. & Hart. 1928)
Twenty stigmata in each mesh .. .. *S. grandis* Herd. (Herd. 1882)

18. Dorsal tubercle not simple 19
Dorsal tubercle simple 20

19. Dorsal tubercle a diffuse, porous area .. .. .. *S. pigmentata* Herd. (Herd. 1906)
Dorsal tubercle a number of separate slits . *C. hartogi* Mich. (Mich. & Hart. 1928)

20. Loop of alimentary canal always extends anteriorly 21
Loop of alimentary canal does not always extend anteriorly 30

21. One gonad on each side 22
More than one gonad on each side 24

22. Nine or 10 bars between folds 23
Four to 6 bars between folds .. .. *S. lapidosa* Herd. (Herd. 1906)

23. Gonads small and rounded .. .. *S. psammodes* Sluit. (Sluit. 1904)
Gonads sausage-shaped .. .. *C. posthuma* Hart. (Mich. & Hart. 1928)

24. Stigmata entire and slits regular 25
Several stigmata fused together .. .. *S. perforata* Sluit. (Hart. 1919)

25. Stigmata with transverse branches .. .. *S. traustedti* Sluit. (Sluit. 1890)
Stigmata without transverse branches 26

26. Large folds with more than 12 longitudinal bars 27
Small folds with less than 12 longitudinal bars 28

27. Short oesophagus, single loop in alimentary canal .. *S. clava* Herd. (Oka 1935)
Long oesophagus, double loop in alimentary canal . *S. plicata* Les.* (Van Name 1945)

28. Gonads in more or less equal numbers on right and left . *S. clara* Hart. (Oka 1935)
Gonads in unequal numbers on right and left 29

29. Stomach pleated internally only .. .. *S. etheridgii* Herd.* (Herd. 1899)
Stomach pleated externally .. .. *S. areolata* Heller (Herd. 1906)

30. Stomach almost spherical 31
Stomach not spherical 33

31. Less than five longitudinal bars in the space between folds
S. irene Hart. (Hart. 1906)
More than five longitudinal bars in the space between folds 32

32. Three gonads on the right side .. .. *S. esther* Hart. (Oka 1910)
Five gonads on the right side .. .. *C. valborg* Hart. (Hart. 1919)

33. Stomach not sharply cut off from intestine 34
Stomach sharply cut off from intestine 36

34. Long, thin gonads 35
Club-shaped gonads .. .. *S. pavementis*, sp. nov.

35. Five long gonads on either side of body .. .. *S. floccosa* Sluit. (Sluit. 1906)
Two long gonads on either side of body .. .. *S. barbaris*, sp. nov.*

36. Stomach long 37
Stomach short . . . . . *S. oligocarpa* Sluit. (Sluit. 1886)
37. One gonad on each side . . . . . *S. orbicularis* Sluit. (Sluit. 1906)
Two gonads on each side . . . . . *S. bicornuta* Sluit. (Brewin 1948)

Other species of *Styela* previously recorded, but not described in sufficient detail for inclusion in the key: Herdman 1882: *Styela exigua, S. convexa, S. radicosa* (Herdman 1882); Traustedt: *Styela longitubis* (see Hartmeyer 1906).

Fig. 1.—*Styela whiteleggii.* External appearance. (× ¼). Fig. 2.—*S. whiteleggii.* Alimentary canal. (× ½). Fig. 3.—*S. ramificata.* Dorsal tubercle. (× 7.5). Fig. 4.—*S. ramificata.* Alimentary canal. (× 7.5). Fig. 5.—*S. ramificata.* Gonads. (× 3.75). Fig. 6.—*S. stolonifera.* Dorsal tubercle. (× 7.5). Fig. 7.—*S. stolonifera.* Alimentary canal and gonads on the left side of the body. (× ½). Fig. 8.—*S. stolonifera.* External appearance of the stalked form. (× ¼). Fig. 9.—*S. plicata.* External appearance of the stalked form. (× ¼). Fig. 10.—*S. plicata.* Siphonal spines. (× 125). Fig. 11.—*S. (Cnemidocarpa) irma.* Alimentary canal and gonads on the left side of the body. (× 2).

(1) Styela whiteleggii Herdman

Figs. 1, 2

1899 *S. whiteleggii* Herdman, p. 40, pl. Cyn. II, figs. 6-7; Cyn. XIV, Figs. 1-6.

External characters.—Body more or less conical, posteriorly rounded and anteriorly tapering to the terminal branchial siphon. The atrial siphon

one-half to one-third of the distance down the dorsal surface. Both external siphons quite conspicuous; the apertures not lobed. Several specimens from Port Jackson (Fig. 1) have relaxed siphons and in that condition both siphons are short but wide and cylindrical and approach the width of the anterior part of the body, so that the branchial siphon is continuous and the animal has apparently a deep cleft between the 2 siphons. Specimens measure 4.5-5 cm. in breadth and 6-7 cm. in length. No further individuals as large as Herdman's type specimens (6 by 10 cm.) have yet been collected. Posteriorly the test is produced into 2 or 3 prop- or root-like processes, of varying lengths, sometimes almost "stalk"-like.

Test.—Thin but tough and leathery; usually brownish in colour and wrinkled, although younger individuals may be smooth. Anteriorly, in all individuals collected to date, there is a thick investment of *Didemnum,* which may encroach further to cover the greater part of the body. There are no spicules or denticles in the siphonal linings, but the lining around the base of the siphon is produced into small knob-shaped papillae.

Atrial tentacles.—Minute and slender, two sizes alternating.

Branchial sac.—Fourteen to 18 internal longitudinal bars on each fold. Herdman records only 6-10, probably representing internal longitudinal bars from one side only. Twelve internal longitudinal bars between the folds. Stigmata regular. Five to 8 stigmata per mesh.

Dorsal lamina.—Plain-edged and moderately wide.

Dorsal tubercle.—As figured by Herdman, but sometimes obliquely placed in the peritubercular area. The spongy appearance is due to the many apertures. It is large and conspicuous, very similar to the condition found in *P. attollens.*

Tentacles.—Simple and more numerous than those recorded by Herdman, who possibly disregarded the smaller tentacles alternating with the 30 larger branchial tentacles.

Alimentary canal (Fig. 2).—A simple, wide loop. Oesophagus short and stomach oval, almost spherical and larger than the width of the intestine. The stomach is oriented transversely across the hinder part of the body. Anal opening with about 8 well-marked lobes.

Gonads.—A large branched and ramifying mass on each side of the body, terminating on each side in 4 or 5 tubular projections around the atrium. These suggest the arrangement of the atrial ends of elongate gonads of typical members of the genus *Styela,* and *S. whiteleggii* may represent a stage intermediate between *Polycarpa* and *Styela* where the polycarps have spread and ramified, and localization and concentration of gonads into elongate organs has begun around the atrium. However, it may be an elaboration of simple elongate ovaries as found in *S. stolonifera.*

Endocarps.—The body wall on both sides is covered with irregularly scattered, wart-like projections, about 30 on the left and 12 on the right.

The loop of the intestine encloses 2-5 of these endocarps, similar to those found enclosed by the loop of the intestine in *P. attollens*, but not as dense, and the orientation and width of the loop differ.

Distribution.—Port Stephens, Port Jackson (Herdman 1899), Port Curtis, 23 fathoms.

(2) Styela ramificata, sp. nov.

Figs. 3-5

External characters.—Body oval; branchial aperture terminal, atrial aperture one-third of the distance down the dorsal surface; both apertures sessile.

Test.—Thin, with sand, shell and weed encrustations; colour greyish.

Mantle.—Not very muscular. Internal siphons very short without spines or spicules in their lining.

Branchial tentacles.—Average size, simple, 26 in number, with smaller rudimentary ones alternating with these.

Dorsal tubercle (Fig. 3).—Circular cushion with S-shaped slit.

Dorsal lamina.—Plain, smooth but not very broad.

Branchial sac.—Four overlapping folds. Longitudinal bars: D L 4 (38) 9 (33) 9 (36) 8 (26) 5 E. These are more closely packed on than between folds. Four stigmata in each mesh. Parastigmatic vessels usually present.

Alimentary canal (Fig. 4).—A single loop transversely placed across posterior end of body; rectum directed anteriorly. The oesophagus of average length widens into a spindle-shaped stomach forming posterior limb of alimentary loop; stomach with internal folds. Anterior limb of the alimentary loop wider than rest of alimentary canal and decreasing in width as it turns anteriorly into the rectum; there is a mesenteric connective across the loop joining the anterior limb and distal end of the stomach. Endocarps large, enclosed in the alimentary loop.

Gonads (Fig. 5).—Covering both sides of body wall except that area occupied by the alimentary canal. They comprise much-branched, tubular ovaries with clumps of testes at various stages along their course. Duct opening dorsally from base of branching structures grouped around and directed towards atriophore.

Endocarps.—In addition to those in the alimentary loop, small cylindrical structures, in the nature of padding, arise from between branches of the gonads.

Relations.—In the nature of gonads this species is allied to the Magellan Straits species, *S. paessleri* Michaelsen, but is distinguished therefrom by the position of testes in relation to ovaries.

Distribution.—One specimen from 2 fathoms, south side, Peel I., Moreton Bay, Queensland, in a scallop shell.

(3) Styela stolonifera Herdman

Figs. 6-8

1899 *Styela stolonifera* Herdman, p. 42, pl. Cyn. XV, figs. 8-11.

External characters.—Appearance generally similar to *S. plicata* but with more distinct siphons (except in young individuals where the apertures are sessile), both usually of equal size and placed adjacently on the apex of the body. (In the specimen from North West Island the atrial siphon is considerably longer and externally the specimen is similar to *P. attollens*). The stalk is subject to great variation. Herdman's specimen from Moreton Bay bears a tuft of root-like processes; these are found in some of the present specimens but there is a tendency to narrowing of the ventral part of the test to produce a stalk (Fig. 8). In one specimen (from 4-5 fathoms) this stalk is longer than the rest of the body and bears only 2 or 3 roots at its base, while it has also become more leathery than the rest of the test. In two small specimens from Tasmania the animals are fixed directly by root-like processes on the ventral part of the test. Largest specimens 3 by 5 cm.

Test.—Leathery, white, not very thick, wrinkled externally.

Mantle.—Thin, not very muscular, extending down into the stalk and roots and usually very adherent to the test. No spines in siphon lining.

Branchial sac.—Four well-marked folds on each side with 11 or 12 bars on each fold (Herdman evidently counted on only one side of the fold for he records only 6). Four to 7 internal longitudinal bars between the folds, and about 10 stigmata in each mesh. Parastigmatic vessels very rarely absent.

Atrial tentacles.—Relatively long but very slender and all of more or less equal length.

Dorsal lamina.—A wide, smooth membrane.

Dorsal tubercle (Fig. 6).—A simply coiled, moderately large tubercle.

Branchial tentacles.—Simple, 16 large alternating with smaller tentacles. Once again Herdman in his original description makes no mention of the smaller tentacles.

Alimentary canal (Fig. 7).—A single, narrow loop, enclosing 2 or 3 endocarps and confined to the postero-ventral part of the body. The oesophagus is fairly long, and the stomach spindle-shaped, pleated internally and sharply demarcated from the intestine. The anal border has about 12 well-marked lobes.

Gonads.—Four or 5 elongated ovaries on the right and 1 or 2 branched on the left, converging to the atrial opening. The testis forms the central core of the gonad; the male ducts arise from the central duct along the mesial surface of the ovary, curve out and around it, carrying testicular lobes between the body wall and ovary so that they are practically surrounded by the ovary. These testicular lobes, although more or less

rounded, would, if not enclosed by ovary, form dendritic testes on the ends of individual ducts as previously typifying the genus *Styela*. The gonads appear to be compact, as typifying the genus *Cnemidocarpa*.

Relations.—This species is very similar in gonad form and distribution to *S. etheridgii* and *S. irma* but differs in the course of the intestine, in the position of the atrial aperture, and in the nature of the anal border.

Distribution.—Moreton Bay (Herdman); North West I., Capricorn Group, Queensland; Strahan, Tas.; Rottnest, W.A. Most plentiful at Moreton Bay, Queensland, but found all around Australia.

(4) Styela plicata Lesueur

Figs. 9, 10

1823 *Ascidia plicata* Lesueur, p. 5, pl. 3, fig. *b*.
1843 *Ascidia plicata* De Kay, p. 259.
1877 *Styela gyrosa* Heller, p. 255, pl. 3, figs. 7-12; pl. 4, figs. 1-8.
1882 *Styela gyrosa* Herdman, p. 155.
1883*a* *Styela plicata* Traustedt, p. 123, 134; pl. 5, fig. 6; pl. 6, fig. 16.
1883*b* *Styela plicata* Traustedt, p. 478, pl. 36, fig. 12.
1885 *Styela plicata* Traustedt, p. 44.
1899 *Styela pinguis* Herdman, p. 40.
1900 *? Styela* sp. Wilson, p. 354.
1905 *Styela plicata* Hartmeyer, p. 384.
1909-11 *Tethyum plicatum* Hartmeyer, pp. 1359, 1630.
1912 *Tethyum plicatum* Van Name, p. 569, fig. 36; pl. 62, figs. 104, 105; pl. 63, fig. 108; pl. 68, fig. 136.
1912*a* *Styela plicata* Huntsman, p. 149.
1912*b* *Styela plicata* Huntsman, pp. 489, 497, fig. 13.
1916 *Styela plicata* Redikorzev, p. 197, pl. 5, figs. 1, 2; figs. 37, 38.
1918 *Styela plicata* Van Name, p. 88.
1918 *Styela plicata* Michaelsen, p. 36.
1921 *Styela plicata* Van Name, p. 435, figs. 102-105.
1927*a* *Styela plicata* Harant, p. 243.
1927*b* *Styela plicata* Harant, p. 7.
1930 *Styela plicata* Van Name, p. 492, figs. 58, 59.
1933 *Styela plicata* Harant and Vernières, p. 31, fig. 46.
1945 *Styela plicata* Van Name, p. 295, pl. 12, figs. 1-3; figs. 192-4.

Synonymy.—The external appearance and nature of the test of specimens described by Herdman as *"S. pinguis"* are identical with specimens of *S. plicata*. Herdman has recorded 9 bars on each fold of the branchial sac but in an examination of his type specimens there were found to be 14-18 bars per fold; thus Herdman had merely recorded the bars on one side of the fold. This again agrees with the condition found in the branchial sac of *S. plicata*. I have counted 35 branchial tentacles and some rudimentary ones on the type specimens of *S. pinguis;* Herdman has recorded only 16—perhaps representing one side only of the mouth. Thus examination of *S. pinguis* leaves no doubt as to its synonymy with *S. plicata*.

External characters.—In the majority of specimens the test is firm, white, and regularly furrowed, usually quite free from attached foreign bodies, and without a stalk as in previous records. Two specimens from zostera beds at the mouth of Gunnamatta Bay have more leathery tests of reddish brown colour, especially posteriorly where they have developed a stalk as long as the body (Fig. 9). One large specimen is covered with a hydroid. The animals in some places grow close together in clusters, and where the object to which large numbers are fixed is small, the posterior part is narrower, tending to a small stalk as in Herdman's figure of *S. pinguis*. Size 3-7 cm. in length, 2.5-5 cm. wide. Siphon lining with curved hollow spines in longitudinal rows (Brewin 1948) (Fig. 10).

Branchial sac.—Six to 10 internal longitudinal bars between the folds and 15-20 internal longitudinal bars on the folds. Usually 5-8 stigmata per mesh.

Dorsal lamina.—A small, plain fold.

Dorsal tubercle.—A simple, U-shaped organ with both horns turned in, directed anteriorly.

Tentacles.—From 30 to 80, simple, closely packed—some very long, two immediate sizes, and some rudimentary.

Alimentary canal.—A double loop occupying the greater part of the left side of the body. The oesophagus is long, the stomach elongate and longitudinally oriented and pleated. The anal opening is fringed by small lobes.

Gonads.—Elongate ovaries fringed with dendritic testicular follicles. On the right 5 or 6 radiating about the atrial opening; on the left 2, one curving strongly posteriorly between the second and third arms of the alimentary canal. In one specimen from Garden Island, Western Australia, 2 gonads occur on the left, the more posterior one branched so that the posterior ramus descends into the alimentary loop, and the anterior ramus runs parallel with the anterior gonad. In another specimen from the same area there was 1 branched gonad on the left, the posterior branch descending into the alimentary loop.

Endocarps.—Fringing the intestine—closely packed and dendritic.

Distribution.—According to Van Name (1945): "Widely distributed on the coasts of the warmer parts of the Atlantic, Pacific and Indian Oceans, including the Mediterranean, but not recorded from the West Coast of America." On the west coast of Australia as far south as Garden Island, and on the east coast the southern limit is at Botany Bay.

(5) Styela (Cnemidocarpa) irma (Hartmeyer)
Fig. 11

1927 *Cnemidocarpa irma* Hartmeyer, p. 168.
1928 *Cnemidocarpa irma* Michaelsen and Hartmeyer, p. 388.

External characters.—Body length 2 in., breadth 1 in. More or less oval, posterior end broader and more rounded, anterior end rather pointed;

in one smaller specimen the test is produced posteriorly into a short, thick stalk. Both apertures are sessile. Branchial aperture anterior and atrial one-third down dorsal surface; in the latter smaller specimen both apertures are apparently anterior on very short siphons (similar to the condition in *S. stolonifera*).

Test.—Fairly thick, tough, opaque, pale pinkish brown colour; the surface covered with smooth, low elevations separated by sharp furrows. Slightly wrinkled around the apertures.

Mantle.—Moderately muscular. The siphons are not lined with spines or spicules but there are small, round projections of the membrane lining the siphon.

Branchial tentacles.—About 30, simple, of average length; rudimentary tentacles alternate with these.

Dorsal tubercle.—A fairly large, round cushion, with U-shaped slit; horns turned to the left, or both turned out, opening directed anteriorly.

Dorsal lamina.—Fairly broad, flat membrane.

Branchial sac.—Four well-formed folds on each side. On the right no longitudinal vessels between the dorsal lamina and first fold; on the left 2 longitudinal vessels. Longitudinal vessels according to the formula: D L 0 (17) 5 (16) 6 (15) 6 (11) 9 E. Stigmata 10-14 in each mesh. Parastigmatic vessels only very rarely present.

Alimentary canal (Fig. 11).—A double loop in the posterior part of the body, the first loop closed, the second widely open. Oesophagus short, sharply cut off from a pear-shaped stomach having internal plications; stomach gradually decreasing to intestine, which curves anteriorly and then posteriorly to form first loop, enclosing a double row of endocarps; rectum turning slightly anteriorly and ending in small, irregular, but well-defined lobes about the anus.

Gonads (Fig. 11).—In the larger specimen 3 long, tubular gonads on each side radiating from the atriophore; in smaller specimens only 2 on each side. The more posterior gonad on the left curves slightly parallel to the second alimentary loop. The ovaries surround and cover the testes, which form the central core (distinguishable by their white, lobed, amorphous state).

Endocarps.—In addition to the tall, laterally flattened endocarps enclosed by the alimentary loop, there are sparsely placed endocarps between the gonads on the body wall.

Relations.—Very closely related to *Styela stolonifera*, especially the smaller specimen with anterior apertures; differs from the latter in rarity of parastigmatic vessels, shape of stomach, and double row of endocarps in alimentary loop.

Distribution.—On the west coast of Australia from Shark Bay to Albany.

(6) Styela etheridgii Herdman

Figs. 12-20

1899 *Styela etheridgii* Herdman, p. 38, pl. Cyn. XIII, figs. 1-8.
1899 *Styela personata* Herdman, p. 41, pl. Cyn. XV, figs. 1-7.
1927 *Cnemidocarpa etheridgii* Hartmeyer, p. 170.

Typical "*etheridgii*" form

Figs. 12-18

External characters.—Large, irregular; some specimens with well-marked external branchial siphons reminiscent of *S. whiteleggii;* in other specimens the outer siphons are indistinct. Branchial aperture terminal and atrial aperture one-third to one-half way down the dorsum.

Mantle.—Very thick, fleshy appearance due mainly to strongly developed muscles and large endocarps on the inner body wall. Inner siphons well marked, especially the branchial siphon. The mantle has prolongations into pockets at the base of test, as Herdman has observed.

Branchial sac.—Four well-developed folds on each side, 7 or 8 between folds and 14-21 bars on each fold. Five to 8 stigmata in each mesh.

Dorsal lamina.—A plain, wide membrane.

Dorsal tubercle.—Shows great variability, as noted by Hartmeyer and Michaelsen (1927). The simplest form shows a U-shaped slit with the right horn turned outward and directed anteriorly; other specimens show an obliquely arranged horseshoe shape, with horns turned in or out; still others show complicated convolutions. The variations in the dorsal tubercles show no direct or apparent relationship to size, maturity, or location of the individual concerned (Figs. 12-16).

Tentacles.—Simple, of varying sizes, but mostly fairly long; total 33-40 in these specimens, but in Herdman's type specimen only a total of 24 recorded.

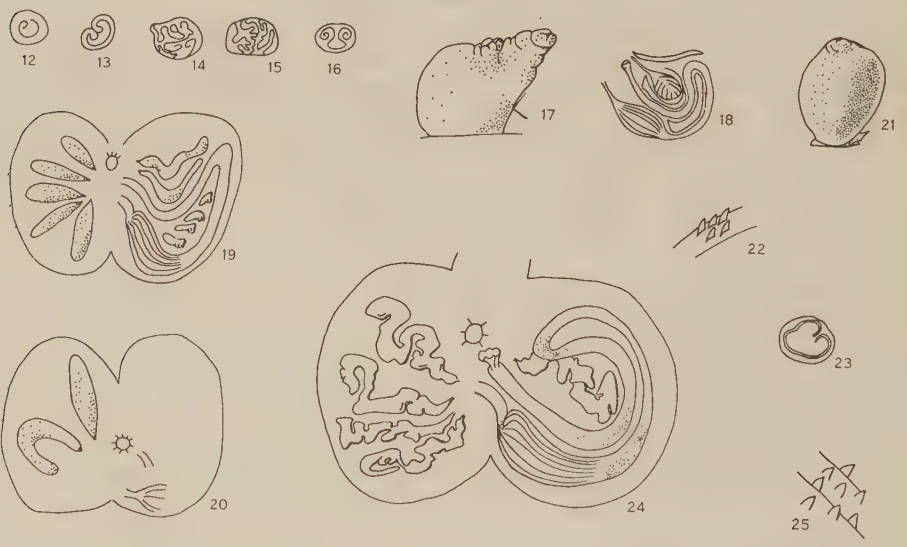
Alimentary canal.—Considerably longer than the organ figured by Herdman (1899). It forms a double loop occupying the greater part of the posterior end of the animal and enclosing a large endocarp in the first loop and another endocarp in the second loop, in which is embedded the gonad. The oesophagus is moderately short, the stomach elongate, transversely oriented and longitudinally pleated internally. Anal border only very slightly lobed or completely smooth.

Gonads.—Also subject to considerable variation, probably due to varying maturity stages in the specimens examined. In many specimens gonads were apparently absent on the right but were represented on the left by a large, more or less spherical mass of tissue in the curve of the intestine and embedded in a large endocarp; and by a longer, narrower organ that extended anteriorly in front of the first loop of the alimentary canal. Both these gonads end in ducts directed toward the atriophore. In other specimens there are 4 or 5 long, narrow, radiating gonads on the

right and a dense and ramifying network of genital tubes in the large endocarp on the left—part representing the more spherical and part the more dorsal elongate ramus. There is a great deal of variation in the degree to which this ramifying network is developed. At times it appears to be absent altogether and the endocarp only remains.

The typical mature condition is represented by 5 tubular radiating gonads on the right and 2 thicker gonads on the left—the anterior elongate, and the posterior spherical.

Distribution.—Spencer's Gulf and St. Vincent's Gulf, S.A.; D'Entrecasteaux Channel, Tas.; Phillip I., Vic.; west coast north to Trigg's I., North Beach; on the east, north to Port Jackson. Largest specimens are found in the south.



Figs. 12-16.—*Styela etheridgii. "etheridgii"* form: variations in the dorsal tubercle of several specimens. (× 7.5). Fig. 17.—*S. etheridgii. "etheridgii"* form: external appearance. (× ¼). Fig. 18.—*S. etheridgii. "etheridgii"* form: gonads and alimentary canal. (× ½). Figs. 19, 20.—*S. etheridgii. "personata"* form: variations in the gonads and alimentary canal of several specimens. (× ½). Fig. 21.—*S. lobata.* External appearance. (× ½). Fig. 22.—*S. lobata.* Siphonal spines. (× 125). Fig. 23.—*S. lobata.* Dorsal tubercle. (× 7.5). Fig. 24.—*S. lobata.* Alimentary canal and gonads. (× ¾). Fig. 25.—*S. barbaris.* Siphonal spines. (× 125).

Typical *"personata"* form

Figs. 19, 20

External characters.—Small forms of 3-5 cm. in length and 2-4 cm. broad. Otherwise they are very similar to *"etheridgii"* form, both in the nature of their test and in the nature and position of their siphons, which are not very well developed and are inconspicuous.

Mantle.—Fairly muscular. Siphon prolongations are well marked and fairly long when extended. Internal atrial siphon about half-way down the dorsal surface.

Branchial sac.—Ten to 12 bars on each fold, 3-7 bars between folds, and 6-10 stigmata per mesh.

Dorsal lamina.—A plain-edged, wide membrane.

Dorsal tubercle.—A simple, horseshoe-shaped slit with horns turned to the right or to the left.

Tentacles.—Simple, widely spaced, about 30-50, large and moderate-sized, interspersed with additional rudimentary tentacles.

Alimentary canal.—A double loop, of which the first extends anteriorly and encloses 3 cylindrical or block-shaped endocarps; the second encloses a number of endocarps although not as extensive and continuous as the larger forms. The oesophagus is short, the stomach elongate, transversely oriented, and longitudinally pleated internally.

The alimentary canal is similar to that of the typical *"etheridgii"* form but in the latter it does not extend anteriorly, and the nature of enclosed endocarps is different.

Gonads (Figs. 19, 20).—Subject to considerable variation. When mature, they form large, sausage-like organs, 2-4 on the left side, curved in the second loop of the alimentary canal, and 1-5 on the right side, radiating about the atrial opening. There is a great similarity between the distribution of gonads in this species and in the typical *"etheridgii"* form.

Gonads		Specimens
Left	Right	
2	0	Type
2	1	Type
4	4	Type
2	2	Rat I., Queensland
2	3	Long Reef, New South Wales
2	4	Long Reef, New South Wales
2	5	Glass and Bottle Reef, Port Jackson
2	2	Chinaman's Beach, Port Jackson

Relations.—There is some similarity to *S. plicata* but here the oesophagus is shorter, the loop of the intestine less well defined, and the gonads on the left are curved in the loop and not into the loop. This species is differentiated from *S. stolonifera* mainly by the orientation and course of the alimentary canal and the position of the apertures.

Distribution.—Port Jackson; Port Curtis, Queensland; Long Reef, N.S.W.; Trigg's I., W.A.

After examination of numbers of specimens and type specimens of *Styela etheridgii* and *S. personata,* it is found that they cannot be separated, for several reasons:

External characters.—Similarity of test, orientation and position of siphons.

Branchial sac.—The difference in numbers of internal longitudinal bars is not beyond the limits of variation due to size or just to normal variation.

Dorsal tubercle.—This organ has already been shown as being extremely variable, and the same types are found in both species.

Alimentary canal.—Similar in course, and in nature of stomach. The apparent extension anteriorly in some specimens, previously identified as *S. personata,* is due to small size and contracted state of specimens.

Gonads.—These have already been shown to be extremely variable. Herdman's type specimen of *S. etheridgii* has 1 large gonad on each side. One of his type specimens of *S. personata* has 2 on the left, as in all other specimens identified as *S. etheridgii,* and 1 *S. etheridgii* type gonad on the right. Another type specimen of *S. personata* has 4 on the right and on the left; and in one there are no gonads visible on the right, which is a condition common in *S. etheridgii* (see Herdman). In other specimens of *S. personata* there are as many as 5 radiating gonads on the right, but in other aspects (e.g. endocarps and size) they are similar to specimens identified as *S. etheridgii.*

The gonads of specimens of *S. personata* may be related to those of smaller specimens of *S. etheridgii* that have not yet reached the stage of development found in *S. etheridgii,* where they have become bulky and thus obscured original arrangement. Variations in number of gonads on the right-hand side are common and it is on the left-hand side that their arrangement is more characteristic. The relationship of ovary to testes in the gonad is as in *S. stolonifera.*

Endocarps.—Where gonads are well developed the large endocarp dorsal to the intestine is absent, but the first gut loop always encloses 3 small endocarps or 1 large endocarp.

The species is characterized mainly by the shape and course of the alimentary canal, by the endocarps, and by the nature of the gonads on the left-hand side of the body.

(7) Styela lobata, sp. nov.

Figs. 21-24

External characters (Fig. 21).—Largest specimens about 5 cm. long and 3 cm. broad. Some are fixed by the whole of the left side (as in certain *Ascidia*) to scallop shells; others fixed posteriorly. Those not fixed by the posterior part of the test have, in this region, a conglomeration of

calcareous particles, mollusc shells, sand, worm tubes; the rest of the test is bare. This demonstrates the tendency in these forms for the posterior part of the test to become fixed to something, even although anchorage of the individual may have been achieved by another portion. Branchial aperture terminal, atrial one-third of the distance down the dorsal surface. Both external siphons are inconspicuous and 4-lobed.

Test.—Thin, leathery, tough, and wrinkled, and of a brownish red colour. Portion of the test lining the branchial siphon bears small, curved, anteriorly directed hooks (Fig. 22).

Mantle.—Fairly muscular; internal siphons short, cylindrical.

Branchial sac.—Four fairly large folds on each side. Internal longitudinal bars well marked and distributed thus: R E 4 (11) 3 (15) 3 (16) 3 (14) 2 DL 2 (16) etc. Transverse vessels of varying widths and showing a certain amount of irregularity, branching, and anastomosing to form networks. Occasionally there are parastigmatic vessels. Stigmata 12-14 in each mesh.

Dorsal lamina.—A fairly wide and smooth membrane.

Dorsal tubercle (Fig. 23).—A large, circular cushion with a simple slit, horseshoe-shaped, with the horns turned in and opening inclined to the left.

Branchial tentacles.—Simple, 56 in all, of varying sizes but large and small alternating.

Alimentary canal (Fig. 24).—A double loop very similar to that of *S. plicata.* Oesophagus not as long as *S. plicata.* Stomach sharply cut off from the oesophagus, comet-shaped, the pyloric end gradually merging into the intestine; it is set postero-dorsally, and is finely plicated internally but the pleating shows through the thin walls. The first loop is narrow but not closed, extends anteriorly, and then turns dorsally and encloses 4 small endocarps in its anterior region. The second loop is wide and also open, and encloses a gonad, partly covered by the pole of the first loop. The rectum is not differentiated from the rest of the intestine and terminates in a 6-lobed anus.

Gonads (Fig. 24).—Compact, elongate, but winding and lobed. On the right are 4 radiating around the atriophore, towards which their ducts open. On the left is a single organ in the second loop of the gut, S-shaped, with its proximal portion partly covered by the pole of the first intestinal loop.

Endocarps.—Only in gut loop.

Relations.—This specimen shows most affinity with *S. lactea* Herd., but differs therefrom in its test, dorsal tubercle, and the arrangement of stigmata in the branchial sac.

Distribution.—In association with *Pyura irregularis* Herd. and *P. hispida* Herd. from scallop beds, D'Entrecasteaux Channel, Tas.; Cronulla, N.S.W.; and from Port Noarlunga, S.A.

(8) Styela barbaris, sp. nov.

Figs. 25, 26

External characters.—Body elongate; 1½ in. long and ¾ in. broad; apertures both anterior on short siphons.

Test.—Tough, whitish brown, slightly wrinkled; colour more intense anteriorly.

Mantle.—Moderately muscular; siphons white internally, with 4 blue stripes bordered with brown, and lined with well-spaced conical spines (Fig. 25).

Branchial tentacles.—Simple, 14 large and smaller alternating, with rudimentary tentacles interspersed.

Dorsal tubercle.—Very small, like that of *S. rectangularis,* with simple U slit directed anteriorly and to the left.

Dorsal lamina.—Smooth, fairly broad.

Branchial sac.—Four small folds with closely packed longitudinal bars; fourth fold very small. Longitudinal bars as follows: D L 10 (21) 11 (22) 11 (21) 9 (12) 8 E. Stigmata long, narrow, 3 or 4 in each mesh; usually with parastigmatic vessels.

Alimentary canal (Fig. 26).—A double loop; the first loop closed and more or less transversely oriented across posterior end of the body; the second loop wide open, formed by the anteriorly directed rectum. Oesophagus short, widening gradually with a short, spindle-shaped stomach with external plications which in turn gradually narrows to intestine, turns anteriorly and then dorsally, and, after a wide curve, extends anteriorly in the rectum, ending in the anus with about 6 well-marked lobes.

Gonads (Fig. 26).—Two long, rather sinuous ovaries, with ducts opening toward the atriophore and extending posteriorly and a little ventrally from there; the gonads lie almost longitudinally in the body. The most posterior on the left-hand side extends down into the open alimentary loop. Testes regularly placed, small dendritic clumps, some distance from the ovary, but around the distal two-thirds of the latter.

Endocarps.—A closely-packed clump enclosed by the first alimentary loop; further scattered endocarps lie between the gonads.

Relations.—Closely related to *S. partita* in nature of gonads, but differs in small number of stigmata and tentacles, in having no colour in the test, and in the absence of tuberculations anteriorly on the test.

Distribution.—South side Peel I., Moreton Bay, Queensland.

(9) Styela rectangularis, sp. nov.

Figs. 27-29

External characters.—Appearance similar to *S. orbicularis* Sluit. Round, flattened antero-posteriorly, fixed by wide base, apertures sessile,

close together in centre of uppermost anterior end of the body. Small specimens ½ in. diameter.

Test.—Gelatinous, fairly thin, especially the posterior basal part. Uppermost part of the test, especially round the siphons, is thicker, more leathery, wrinkled.

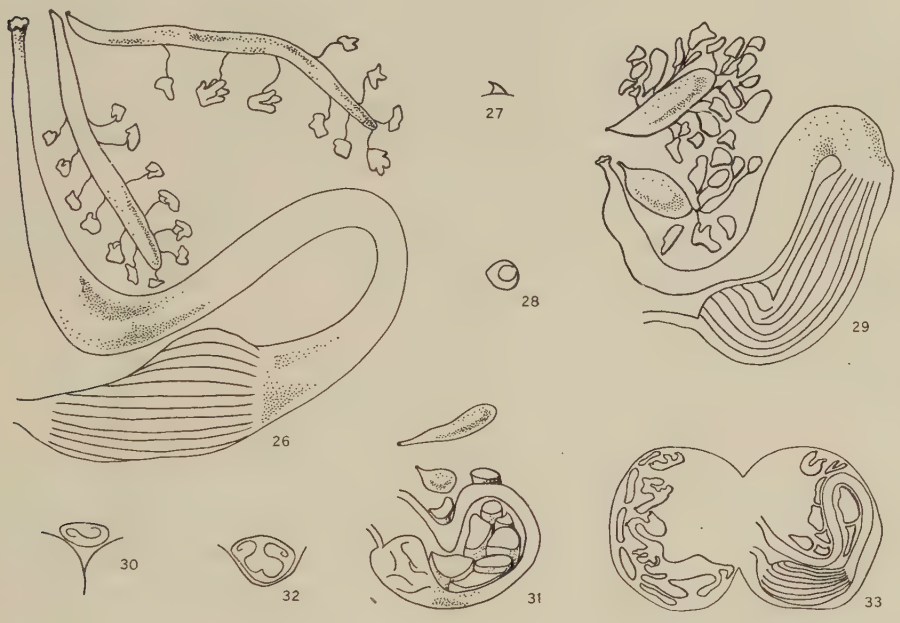


Fig. 26.—*Styela barbaris.* Alimentary canal and gonads. (× 7.5). Fig. 27.—*S. rectangularis.* Siphonal spines. (× 125). Fig. 28.—*S. rectangularis.* Dorsal tubercle. (× 4). Fig. 29.—*S. rectangularis.* Alimentary canal and gonad on the left side of the body. (× 4). Fig. 30.—*S. pavementis.* Dorsal tubercle. (× 7.5). Fig. 31.—*S. pavementis.* Alimentary canal and gonads. (× 1). Fig. 32.—*Astereocarpa cerea.* Dorsal tubercle. (× 7.5). Fig. 33.—*A. cerea.* Alimentary canal and gonads. (× ¾).

Mantle.—Not very muscular. Internal siphons short, but lined with small, triangular spines (Fig. 27). Siphon lining has white and red stripes.

Branchial tentacles.—Simple, 24 of various sizes.

Dorsal tubercle (Fig. 28).—Very small with a U-shaped slit directed anteriorly and to the left, as in *S. orbicularis* Sluiter.

Dorsal lamina.—Smooth, broad.

Branchial sac.—Four definite folds on either side of the body. Longitudinal bars close together on the folds: D L 2 (12) 2 (9) 2 (8) 2 (11) 2 E. Seven to 12 stigmata in meshes between the folds; parastigmatic vessels usually present.

Alimentary canal (Fig. 29).—A double loop, the pole of the first loop higher than the anus, but not extending very far anteriorly. Oesophagus not very long, widening abruptly into a long, rectangular stomach which bends anteriorly after about the first third of its length; the intestine turns back alongside the stomach, curves around and turns anteriorly to the rectum, ending in a small anus, with 9 well-marked slightly bidentate lobes.

Gonads (Fig. 29).—Two on each side of the body. On the left is a short, rounded ovary in the second alimentary loop, and there is a longer ovary further to the anterior, both gonads being directed toward the atriophore; arrangement similar on the left. Testes branched, dendritic lobes in the body wall, some distance from and around the ovaries; in some cases their ducts have united before they reach the ovary.

Relations.—Very similar to *S. orbicularis* Sluiter in external appearance and form of the dorsal tubercle; differs in branchial sac and the length of the stomach.

Distribution.—Fremantle Harbour, W.A.

(10) Styela pavementis, sp. nov.

Figs. 30, 31

External characters.—Body vertically elongate, owing to posterior extension of test to form a stalk-like structure as long and wide as the rest of the body. Branchial aperture on short siphon, terminal; atrial aperture sessile and one-third distance dorsally. Small specimen, $\frac{1}{2}$ in. long, $\frac{1}{2}$ in. broad.

Test.—Thickest posteriorly where stalk arises, but otherwise thin, irregular, semi-transparent, yellowish white.

Mantle.—The body inside the test is small, oval, and moderately muscular. Siphons are not lined with spines.

Branchial tentacles.—Simple.

Dorsal tubercle (Fig. 30).—Transversely elliptical with a transversely oriented S-shaped slit. Mesentery around the tubercle raised into pavement-like blisters.

Dorsal lamina.—Smooth, fairly broad.

Branchial sac.—With 4 well-marked folds anteriorly, but these posteriorly flatten out to a condensation of longitudinal bars. Longitudinal bars: D L 0 (9) 3 (9) 3 (10) 4 (8) 4 E. Stigmata 3 or 4 per mesh, regular, elongate, sometimes with a parastigmatic vessel.

Alimentary canal (Fig. 31).—Double loop; the first loop wide, deep, almost closed; the second shallow, open. The oesophagus opens from half-way down the branchial sac, is short, and opens abruptly into the widest end of pear-shaped stomach, which is almost smooth externally, though marked with irregular sulcations (not longitudinal); internally

the stomach is unusual in having deep plications that are not seen through the stomach wall. Anal border with irregular lobes.

Gonads.—Two club-shaped gonads on either side of the body.

Relations.—Though this species may be distinguished from all others in the shape and nature of the stomach, in other characters it closely resembles many other species of the genus.

Distribution.—Thompson's Bay, Rottnest, W.A.

Genus ASTEREOCARPA Brewin

(1) Astereocarpa cerea (Sluiter)

Figs. 32, 33

1878 *Styela humilis* Heller, p. 108, pl. 1, fig. 7.
1891 *Styela humilis* Herdman, p. 580.
1900 *Styela cerea* Sluiter, p. 24, pl. 3, figs. 9-11.
1909 *Dendrodoa gregaria* Kesteven, p. 291; pl. 25, figs. 1-3; pl. 26, fig. 7; pl. 27, figs. 1-5.
1909-11 *Pandocia gregaria* Hartmeyer, p. 1484.
1911 *Pandocia gregoria* Schepotieff, p. 12.
1912 *Tethyum assymetron* Hartmeyer, p. 253, pl. 253, fig. 6, pl. 41, figs. 5-7.
1916 *Cnemidocarpa robinsoni* Hartmeyer, p. 224, figs. 10-13.
1920 *Cnemidocarpa robinsoni* Hartmeyer, p. 131.
1927 *Cnemidocarpa humilis, C. cerea, C. gregaria, C. assymetra* Hartmeyer and Michaelsen, pp. 173-5.
1945 *Cnemidocarpa robinsoni* Van Name, p. 271.
1946 *Astereocarpa cerea* Brewin, p. 124.

External characters.—Almost spherical individuals of $2\frac{1}{2}$-3 cm. Both siphons are anteriorly directed and closely approximated, with a cleft between.

Test.—Thin, leathery, pale brown in colour, fairly smooth, but around the apertures it is produced into numerous small papillae bearing minute pointed processes. The portion of test lining the siphon bears minute pointed scales.

Mantle.—Fairly muscular.

Branchial sac.—With 4 folds on each side of the body. Longitudinal bars as follows: E 3 (8) 3 (8) 2 (10) 2 (7) 0 D L. Stigmata in each mesh 12-15. Transverse vessels all of the same width. Occasionally parastigmatic vessels present.

Dorsal lamina.—A plain-bordered, smooth membrane.

Dorsal tubercle (Fig. 32).—Large, practically completely filling the peritubercular area, with a simple symmetrical slit with horns turned outwards and opening anteriorly.

Branchial tentacles.—Fifteen large, alternating with same number of smaller tentacles and minute rudimentary tentacles interspersed.

Alimentary canal (Fig. 33).—A double loop; the first loop narrow, enclosing 2 large endocarps; the second loop wide open, with endocarps

bordering the prerectal portion of the intestine. Oesophagus fairly short; stomach long and spindle-shaped, with minute plications internally. The anal border has 2 smooth lips. The pole of the first loop extends anteriorly.

Gonads (Fig. 33).—One or 2 on the left, anterior to the pole of the first loop. On the right are 4 or 5 or less, according to the degree of anastomosis between them. On the left they are arranged around the ventro-posterior part of the body wall. The gonads, as described by previous workers, are more or less stellate and the distal portion of each arm bears a duct aperture. All of the gonoduct apertures are directed ventrally, and the dorsally directed arms of the gonad are turned, in some cases, slightly ventrally to facilitate this, as in Hartmeyer's specimen of *C. gregaria* (Kest.) from Hobart.

Endocarps.—In addition to those in relation to the gut there are 5 along the ventral side of the gonads on the right-hand side of the body.

Relations.—Hartmeyer (1927) suggested the possible synonymy of all the forms in this group. This suggestion was repeated by Van Name (1945) and by Brewin (1946). The form of the gonads and their ducts is variable and no constant differences exist between the very full descriptions of the species available. Brewin (1946) describes gonoducts on the free ends of the gonads (both dorsal and ventral), which are arranged in a regular stellate form; she has also described variations of this where fusion of the gonads has led to the condition described for *C. cerea* (Sluit.), *C. humilis* (Heller), *C. robinsoni* (Hart.), and *C. gregaria* (Kest.).

Distribution.—South Africa, New Zealand, Tasmania, (D'Entrecasteaux Channel), South Australia, Malayan Archipelago. Therefore this rare species is widely distributed in the Indo-Pacific area.

Genus POLYCARPA Heller

Key to Species of the Genus Polycarpa

1. Large rounded endocarp enclosed by alimentary canal 2
   No large rounded endocarp enclosed by alimentary canal 14
2. Dioecious gonads . . . . . *P. japonica* Mich. (Mich. & Hart. 1928)
   Hermaphrodite gonads 3
3. Several openings on dorsal tubercle 4
   Single opening on dorsal tubercle 5
4. No stomach enlargement . . . . . *P. bassi* Herd. (Herd. 1882)
   With stomach demarcation . . . . . *P. cryptocarpa* Sluit. (Hart. 1906)
5. Two gonads on each side . . . . . *P. adjornseni* Mich. (Mich. & Hart. 1928)
   Considerably more than 2 gonads on each side 6
6. Gonads in rows 7
   Gonads not in a row 12
7. Gonads in 1 row . . . . . *P. unilineata*, sp. nov.*
   Gonads in more than 1 row 8
8. With hairs on the test . . . . . *P. molguloides* Herd. (Herd. 1882)
   Without hairs on the test 9

9. Test yellowish brown 10
Test black 11
10. Body wall thin; no longitudinal muscle bands . *P. obtecta* Traust.* (Van Name 1945)
Muscular, thick body wall; longitudinal muscle bands present
P. moebii Mich.* (Mich. & Hart. 1928)
11. Numerous small specimens growing together .. *P. nigricans* Heller (Hart. 1905)
Large, isolated specimens .. .. *P. obscura* Heller* (Mich. & Hart. 1928)
12. About 200 gonads on each side .. .. *P. stephenensis* Herd.* (Herd. 1899)
Not more than 100 gonads on each side 13
13. Circular endocarp .. .. *P. maculata* Hart. (Hart. 1906)
Endocarp not circular .. .. *P. pedunculata* Heller* (Mich. & Hart. 1928)
14. Alimentary canal behind branchial sac .. .. .. *P. herdmani* Sluit. (Sluit. 1886)
Alimentary canal at left of branchial sac 15
15. Dorsal lamina not plain or smooth 16
Dorsal lamina plain and smooth 18
16. Branchial folds occur as rounded pads with a slit between them
P. fungiformis Herd.* (Herd. 1882)
Branchial folds not merely rounded pads 17
17. Two or 3 bars between folds .. .. *P. elsa* Hart. (Hart. 1906)
Six bars between folds .. .. *P. alentura* Herd. (Herd. 1906)
also *P. phaula* Sluit. (Sluit. 1904)†
18. Polycarps with calcareous spicules .. .. *P. minuta* Herd. (Herd. 1882)
Polycarps without calcareous spicules 19
19. Connective tissue loop connecting 2 limbs of the intestinal loop
P. aurita (Sluit.)* (Hart. 1919)
Without connective tissue loop connecting 2 limbs of the intestinal loop 20
20. Gonads in 1 or 2 rows 21
Gonads not in rows, or in numerous rows 28
21. Gonads not in rows beneath endostyle 22
Gonads in rows beneath endostyle 24
22. Gonads in centre of body wall .. .. *P. intestinata*, sp. nov.*
Gonads in rows around atriopore 23
23. Single row of polycarps .. .. *P. ambonensis* (Sluit.) (Sluit. 1904)
Double row of polycarps .. .. *P. olitoria* Sluit. (Sluit. 1904)
24. No longitudinal bars between dorsal lamina and first fold 25
With longitudinal bars between dorsal lamina and first fold 26
25. Alimentary canal forms closed loop .. .. *P. incubita* (Sluit.) (Sluit. 1904)
Alimentary canal does not form loop .. *P. procera* (Sluit.) (Mich. & Hart. 1928)
26. Two stigmata in each mesh .. .. *P. doderleinii* Hart. (Hart. 1906)
More than 6 stigmata in each mesh 27
27. Six polycarps in each row .. .. *P. albopunctata* Sluit. (Sluit. 1904)
More than 6 polycarps in each row .. .. *P. tinctor* Herd.* (Herd. 1899)
28. Branchial folds rudimentary 29
Branchial folds not rudimentary 31
29. First fold well developed .. .. *P. reducta* (Sluit.) (Sluit. 1904)
No well-developed folds 30
30. Two bars in interspace .. .. *P. colletti* Herd. (Herd. 1906)
Fifteen to 17 bars in interspace .. .. *P. thelypanes* Sluit.* (Sluit. 1904)
31. Dorsal tubercle large, complicated, filling the peritubercular area 32
Dorsal tubercle does not always completely fill the peritubercular area 33

† These species are indistinguishable from descriptions.

32. Long anal lobes . . . . . *P. attollens* Herd.* (Herd. 1899)
Short anal lobes . . . . . *P. aurata* (Q. & G.)* (Mich. & Hart. 1928)
33. With spicules in mantle and branchial sac . *P. albomarginata* (Sluit.) (Sluit. 1904)
Without spicules in mantle and branchial sac 34
34. Without longitudinal bars between folds . . . *P. decipiens* Herd. (Herd. 1906)
With longitudinal bars between folds 35
35. Dorsal lamina or endostyle, or both, following a winding course 36
Dorsal lamina and endostyle straight 37
36. Dorsal lamina and endostyle winding anteriorly . . *P. papillata* Sluit. (Sluit. 1885)
Endostyle forms a spiral posteriorly . . . . . *P. spiralis* Sluit. (Sluit. 1891)
37. Gonads elongate 38
Gonads rounded or oval 48
38. Opening of dorsal tubercle broken into several parts
P. cylindrica (Sluit.) (Sluit. 1904)
Opening of dorsal tubercle entire 39
39. Gonads 30 or more 40
Gonads less than 30 41
40. Ten to 20 bars between folds . . . *C. polyphlebodes* (Hart.) (Mich. & Hart. 1928)
Six to 8 bars between folds . . . . . *P. intermedia* Hart (Hart. 1919)
Two or 3 bars between folds . . . . . *P. fertilis* Hart. (Hart. 1906)
41. Alimentary canal a small, compact mass . . . *P. palkensis* Herd. (Herd. 1906)
Alimentary canal an open or closed loop 42
42. Transverse vessels curved . . . . . *P. patens* (Sluit.) (Sluit. 1904)
Transverse vessels straight 43
43. Six bars on each fold . . . . . *P. mutilans* Herd. (Herd. 1906)
Nine or 10 bars on each fold 44
44. Three or 4 bars between folds 45
Five to 8 bars between folds . . . . . *P. hartmeyeri* Mich. (Mich. & Hart 1928)
45. Six large and 6 small tentacles . . . . . *P. sluiteri* Herd. (Herd. 1906)
More than 12 tentacles 46
46. Siphons at opposite ends of the body . . . . . *P. willisi* Herd. (Herd. 1906)
Siphons not at opposite ends of the body 47
47. Both alimentary loops open . . . . . *P. elata* Heller (Mich. 1905)
One alimentary loop closed . . . . . *P. capricornia*, sp. nov.*
48. Transverse vessels irregular, resulting in triangular meshes
P. pustulosa (Sluit.) (Sluit. 1904)
Transverse vessels run a regular course 49
49. Dorsal tubercle in a long peritubercular area . . *P. captiosa* (Sluit.) (Sluit. 1904)
Dorsal tubercle in a short, triangular peritubercular area 50
50. Small, inconspicuous dorsal tubercle . . . . . *P. twynami* Herd. (Herd. 1906)
Dorsal tubercle conspicuous 51
51. Twelve bars in the interspace . . . . . *P. irregularis* Herd. (Herd. 1882)
Less than 12 bars in the interspace 52
52. No enlargement for the stomach . . . . . *P. circumarata* (Sluit.) (Sluit. 1904)
Stomach clearly enlarged 53
53. Stomach not ridged . . . . . *P. assymmetrica* (Sluit.) (Sluit. 1904)
Stomach ridged 54
54. Stomach ridged externally . . . . . *P. chalmersi* Herd. (Herd. 1906)
Stomach ridged only internally 55
55. Simple loop in alimentary canal 56
One and one-half to 2 loops in alimentary canal 57

56. Quadrate shape externally . . . . . *P. manaarensis* Herd. (Herd. 1906)
Upright cylindrical shape externally . . . . . *P. rigida* Herd.* (Sluit. 1904)
57. Two loops in alimentary canal . . . . *P. reniformis* (Sluit.) (Mich. & Hart. 1928)
One and one-half loops in alimentary canal 58
58. Four to 6 stigmata 59
Ten to 12 stigmata 60
59. Four or 5 bars between folds . . . . . *P. sacciformis* Herd.* (Herd. 1899)
Eight bars between folds . . . . . *P. sluiteri* Herd.* (Herd. 1899)
60. Open loops in alimentary canal . . . . . *P. solvens* (Sluit.) (Mich. & Hart. 1928)
Closed loops in alimentary canal . . . . . *P. nebulosa* Heller (Mich. 1905)

Fig. 34.—*Polycarpa stephenensis.* External appearance. ($\times \frac{1}{4}$). Figs. 35, 36.—*P. stephenensis.* Dorsal tubercles from two individuals. ($\times$ 7.5). Fig. 37.—*P. pedunculata.* External appearance. ($\times \frac{1}{4}$). Fig. 38.—*P. pedunculata.* Alimentary canal. ($\times \frac{1}{2}$). Fig. 39.—*P. tinctor.* Dorsal tubercle. ($\times$ 7.5). Fig. 40.—*P. tinctor.* Alimentary canal. ($\times$ 1). Fig. 41.—*P. attollens.* External appearance. ($\times \frac{1}{4}$). Figs. 42, 43.—*P. attollens.* Dorsal tubercles from two individuals. ($\times$ 7.5). Fig. 44.—*P. attollens.* Alimentary canal. ($\times \frac{1}{2}$). Fig. 45.—*P. sluiteri.* Alimentary canal. ($\times$ 2.5). Fig. 46.—*P. aurata.* Alimentary canal. ($\times \frac{3}{4}$). Fig. 47.—*P. thelypanes.* Alimentary canal and gonads. ($\times$ 1). Fig. 48.—*P. intestinata.* Dorsal tubercle. ($\times$ 7.5).

Note.—Herdman has described two distinct species of *Polycarpa* under the specific name of *sluiteri*—in 1899 and 1906 respectively. The latter (45 in the key above) therefore requires a new specific name.

Owing to insufficient description, the following species have not been included in the key: *P. sobria* (Sluiter) (1904), *P. contecta* (Sluiter) (1904), *P. biforis* (Sluiter) (1904), *P. nutrix* (Sluiter) (1904), *P. glebosa* (Sluiter) (1904), *P. palinorosa* (Sluiter) (1904), *P. argentata* (Sluiter) (1904), *P. mollis* Heller (1878), and *P. jacksoniana* Herdman (1899).

(1) Polycarpa stephenensis Herdman

Figs. 34-36

1899 *P. stephenensis* Herdman, p. 45, pl. Cyn. XVII, figs. 1-5.

External characters (Fig. 34).—Body almost rectangular, with the apertures close together at the top.

Test.—Leathery but soft. Thick posteriorly. One specimen from Lakes Entrance had a gelatinous test coated with sand rather than leathery.

Mantle.—Opaque but not very muscular.

Branchial sac.—Four well-marked folds on each side. Between the most dorsal fold on either side and the dorsal lamina there are no internal longitudinal bars; on the right-hand side there is a plain membrane and on the left-hand side the fold lies immediately against the lamina. Fifteen to 20 longitudinal bars on each fold and invariably 3 bars between the folds. Seven to 12 stigmata in each mesh.

Dorsal lamina.—A plain, narrow membrane.

Dorsal tubercle (Figs. 35, 36).—Transversely elongate, almost rectangular, large; in one specimen both horns were turned out, in other specimens the tubercle was S-shaped; but there is a considerable variation, although the pattern is never very complex.

Tentacles.—Simple, about 50, of 3 sizes.

Alimentary canal.—A double loop (Herdman 1899, Cyn. XVII fig. 4), enclosing a large endocarp in the first loop. Stomach oval and transversely oriented, smooth, without folds. The alimentary canal does not extend anteriorly and terminates, about the middle of the body, in the anus, which has very small, regular lobes on the border.

Gonads.—Very small, numerous, about 10-20 in quadrangular areas covering both lateral body walls. On the left-hand side they cease abruptly posteriorly and do not extend back beyond the alimentary canal.

Distribution.—Port Stephens, N.S.W.; Lakes Entrance, Vic.

(2) Polycarpa pedunculata Heller

Figs. 37, 38

1878 *Polycarpa pedunculata* Heller, p. 106, pl. 6, fig. 30 (f. *typica*).
1880-81 *P. viridis* Herdman, p. 74 (f. *viridis*).
1880-81 *P. radicata* Herdman, p. 74 (f. *typica*).
1882 *P. viridis* Herdman, p. 168, pl. 21, figs. 7-14 (f. *viridis*).
1882 *P. radicata* Herdman, p. 181, pl. 24, figs. 3-5 (f. *typica*).

1899 *P. viridis* Herdman, p. 47, pl. Cyn. 18, figs. 1, 5-10 (f. *viridis*).
1905 *P. pedunculata* Michaelsen, p. 98, pl. Cyn. 4, figs. 9, 10 (f. *typica*).
1909 *Pandocia pedunculata* + *Polycarpa viridis* Hartmeyer, p. 1364 (f. *typica* bzw. f. *viridis*).
1919 *Polycarpa pedunculata* Hartmeyer, p. 48, pl. 1, figs. 22 and 23 (f. *typica*).
1928 *P. pedunculata* Hartmeyer and Michaelsen, p. 366.

External characters (Fig. 37).—Small, almost triangular, the apex ventral, with root-like processes; 4 by 4.5 cm. Laterally flattened.

Test.—Sometimes covered with sand, and tough, leathery, smooth, without furrows or knobs, and without foreign bodies. Ventrally the test is produced into a stalk of varying lengths with the root-like processes at its base. As Herdman (1899) has remarked: "There are 2 series or varieties amongst these specimens—the sandy one with yellowish tests and brown mantles and branchial sac, and those that have very little sand and show a green colour in both test and mantle; but there are no points of constant structural difference that would enable these to be defined as distinct species." Nor was there, apparently, anything in their distribution that implied a regional variation since both types were found in the same places in equal numbers. On the whole the specimens of yellowish colour had longer stalks.

Branchial sac.—Between the first dorsal fold and the dorsal lamina on both sides in some specimens, and on the left only in others, there are often no internal longitudinal bars. On the folds there are 10-15 longitudinal bars; between the folds 5 or 6 bars. About 10 stigmata occur in each of the meshes.

Dorsal lamina.—A smooth, median ridge.

Dorsal tubercle.—U-shaped, always simple and without complicated convolutions. Horns may both be turned to right or left. It is large and completely fills the peritubercular space.

Tentacles.—Simple, about 50, closely placed, of varying sizes, long and shorter alternating.

Alimentary canal (Fig. 38).—A double loop, confined to the posterior end of the body. The first loop encloses an elongate endocarp, sometimes replaced by 2 rounded endocarps. Stomach transversely oriented and elongate. Oesophagus short.

Gonads.—Scattered over the lateral body walls, moderately small and flask-shaped, with ducts directed toward atrial opening. Body wall often thickened by endocarp-like tissue in quadrangular areas, in which the gonads are scattered.

Relations.—The dorsal tubercle shows a strong resemblance to that of *P. aurita*, and the alimentary canals of both species are also similar. The endocarps and gonads, however, are distinctive in both forms, as is also the nature of the test. The alimentary canal is relatively small, in the posterior end of the body, and is thus distinguished from related forms, *P. moebii*, *P. obscura*, and *P. obtecta*.

Distribution.—Found all around the Australian coast: Cape Jaubert, Shark Bay, Cockburn Sound, Albany, W.A.; Bass Strait; Tasmania (Oyster Bay); Port Jackson, N.S.W.; Twofold Bay, North West I., Capricorn Group, Cairns, Queensland; New Guinea.

(3) Polycarpa fungiformis Herdman

1899 *Polycarpa fungiformis* Herdman, pl. Cyn. XVI, figs. 1-10.

Distribution.—Moreton Bay, Queensland.

Only the type specimen was available. This was in a bad state of preservation and further description is impossible.

(4) Polycarpa aurita Sluiter

1890 *Styela aurita* Sluiter, p. 338, pl. 2, figs. 12, 13.
1904 *Styela aurita* Sluiter, p. 59.
1908 *Polycarpa erecta* Pizon, p. 202, pl. 9, figs. 5-7.
1919 *Polycarpa aurita* Sluiter, p. 81, pl. 2, figs. 43-7.

External characters.—Very like *P. pedunculata* in shape, but the siphons are more distinct and placed at either end of the upper surface.

Alimentary canal and gonads.—Also similar, but there is no enclosed endocarp.

Dorsal tubercle.—Of complex pattern.

Distribution.—Malaya and North Australia at Cape Jaubert in the west and the Great Barrier Reef in the east.

(5) Polycarpa tinctor (Quoy and Gaimard)

Figs. 39, 40

1834 *Ascidia tinctor* Quoy & Gaimard, p. 608, pl. Xei, figs. 1 and 2.
1882 *Polycarpa tinctor* Herdman, p. 170, pl. XXI, figs. 1-6.
1899 *Polycarpa tinctor* Herdman, p. 51, pl. Cyn. XX, fig. 9.

External characters.—Elongate, almost rectangular body, not fixed, with a terminal branchial siphon and a protruding atrial siphon about one-third of the way down the dorsal margin. The body is laterally compressed, 4-5 cm. long, 1-1.5 cm. wide.

Test.—Brittle, thickly embedded with sand.

Mantle.—Very muscular.

Branchial sac.—With four well-marked folds on either side. Each fold bears 10-16 closely set internal longitudinal bars, and between folds there are 4-6 longitudinal bars. The stigmata number 6-8 in each mesh.

Dorsal lamina.—A plain, narrow membrane.

Dorsal tubercle (Fig. 39).—Simple, with S-shaped slit turned either to left or right, or V-shaped with both horns turned spirally outwards. It is almost circular, oblong, and obliquely set in the peritubercular area.

Branchial tentacles.—Simple, not very long, and numbering about 25, with rudimentary ones alternating. Atrial tentacles also present.

Alimentary canal (Fig. 40).—Forming a longitudinal S shape. Oesophagus narrow, short; stomach rounded, almost globular, transversely oriented and ridged internally, these ridges showing through the transparent stomach walls. Intestine sharply cut off from the stomach, turning anteriorly, then dorsally, then anteriorly for some distance, and terminating just below the atriophore in an unlobed atrial opening.

Gonads.—Small, quadrangular polycarps in closely set double rows below the endostyle.

Endocarps.—Minute and scattered densely over right and left lateral body walls.

Relations.—Differs from *P. procera* mainly in large number of internal longitudinal bars present.

Distribution.—Port Jackson, off Wattamolla (52-71 fathoms), N.S.W.

(6) Polycarpa attollens Herdman
Figs. 41-44

1899 *P. attollens* Herdman, p. 53, pl. Cyn. XX, figs. 6-8.

External characters.—Body ovate, with a long anterior projection bearing the branchial aperture at its extremity. The atrial aperture is half-way down the dorsal side on an obliquely protruding siphon. The surface of the leathery test is marked by furrows and sulci. On one specimen from Hervey Bay (Fig. 41) the ventral part of the test has been produced into a stalk about one-half the length of the body, bearing root-like processes basally. In other specimens the root-like processes spring directly from the base of the test.

Mantle.—Moderately thick and muscular.

Branchial sac.—With 4 well-marked and overlapping folds on either side of the body. There are 8-10 bars between the folds and 18-23 on the folds; also 6-8 stigmata in each mesh.

Dorsal lamina.—A plain membrane.

Dorsal tubercle (Figs. 42, 43).—Large and invariably entirely filling the peritubercular area. The surface is marked by a variable although always complicated pattern—either a convoluted slit or a number of separate and entire apertures as in *P. aurata* (vide Herdman 1899: "double sinuous line . . . interrupted once or twice at most"). But the occurrence of a number of separate apertures in the dorsal tubercle indicates that this is not as characteristic as Herdman thought.

Tentacles.—Forty of much the same size, with rudimentary tentacles between.

Alimentary canal (Fig. 44).—Restricted to the posterior end of the body and forming with the stomach a longitudinally oriented loop. The

intestine or second limb of the loop is curved so that in the middle part of its course it meets the stomach; the loop is in some specimens more open than in others. Proximally it encloses, with the stomach, numerous closely packed and upright endocarps, and distally it terminates in a lobed anal opening. The oesophagus is short, the stomach spindle-shaped.

Gonads.—Small, very numerous, upright cylindrical bodies interspersed with endocarps, particularly dense in a longitudinal arc along the middle of the lateral body wall.

Distribution.—Port Jackson (Herdman), N.S.W.; Moreton Bay; North West I., Capricorn Group; Hervey Bay, Double I., 33 fathoms, Gatecombe Head, Port Curtis, 9-12 fathoms, Queensland; and Solomon Is. Therefore generally tropical Indo-Pacific area.

(7) Polycarpa sluiteri Herdman

Fig. 45

1899 *Polycarpa sluiteri* Herdman, p. 46, pl. Cyn. IV, fig. 1, pl. Cyn. XVII, figs. 6-9.

Relations.—One specimen only of this species was collected by Herdman. It is in a bad state of preservation and the alimentary canal is the only part at all distinguishable (Fig. 45). It runs a similar course to that of *P. tinctor* and has an internally pleated stomach, but it is oval rather than globular. Externally it is very similar to *P. tinctor*. It is distinct from the latter in the arrangement and form of its gonads, as described by Herdman, and in the fact that this is a fixed form.

Herdman described a species of *Polycarpa* under this name in 1906 from Ceylon—according to his descriptions and figures the two forms differ in the nature of their test, in the nature of the folds of the branchial sac, in the number of bars between the folds, and in the number of stigmata. Also the gonads are different. Thus re-examination and re-naming of the Ceylonese species is required.

Distribution.—Port Jackson, N.S.W.

(8) Polycarpa aurata (Quoy and Gaimard) f. clavata Hartmeyer

Fig. 46

1834 *Ascidia aurata* Quoy and Gaimard, p. 608, pl. 91, fig. 3.
1882 *Polycarpa obscura* and *P. pedata* Herdman, p. 179, pl. 23, figs. 9-13; p. 180, pl. 24, figs. 1, 2.
1890 *Styela psoloessa* Sluiter, p. 337, pl. 1, figs. 10, 11.
1895 *Styela* (*Polycarpa*) *pneumonades* Sluiter, p. 179, pl. 10, figs. 1-3.
?1899 *Polycarpa aurata* var. *plana* Herdman, p. 51, 110, pl. Cyn. 20, figs. 1-5.
1905 *Polycarpa sulcata* Michaelsen, p. 97.
1908 *Polycarpa pedunculata* Pizon, p. 216, pl. 12, figs. 21-4.
1909 *Pandocia pizoni* (nom. nov. pro *Polycarpa pedunculata* Piz.) Hartmeyer, p. 1484.
1912 *Pandocia* (*Polycarpa*) *botryllifera* Michaelsen, p. 143, figs. 10-12.
1919 *Polycarpa aurata* Hartmeyer, p. 40, pl. 1, figs. 17, 18.
1928 *Polycarpa aurata* f. *clavata* Michaelsen and Hartmeyer, p. 363, fig. 28.

External characters.—Body club-shaped, 2 in. long, 1 in. wide. Both openings sessile, on the dorsal surface. The animal is standing on its head (as in *Pyura pachydermatina* etc.) since the atrial opening is uppermost and from the anterior end of the test is a stalk-like projection, very fleshy, and almost as wide as the test of the animal. On this stalk-like projection, by which the animal is fixed, there are scattered circular, dark-pigmented areas, richly supplied with blood vessels. Their function may possibly be sensory.

Test.—Thick, gelatinous, whitish in colour, clear, with slight furrows externally.

Mantle.—Not very muscular; there is a long projection from its anterior end down into the stalk.

Branchial tentacles.—Long, simple, 24, with rudimentary tentacles interspersed.

Dorsal lamina.—Plain, smooth, but rather thick and rounded.

Dorsal tubercle.—A fleshy endocarp-like triangular cushion, almost completely occupying the peritubercular area. The left horn of the U-shaped slit is turned in.

Branchial sac.—Tough, 4 folds on each side, almost parallel longitudinally; folds low, spread. Longitudinal bars very close together, strong and wide; D L 2 (12) 3 (9) 3 (10) 2 (10) 1 E. Seven to 12 stigmata per mesh.

Alimentary canal (Fig. 46).—Occupies posterior half to one-third of the body. The tube is wide, there is no stomach enlargement, the first loop of the double narrow loop enclosing about 4 long, narrow endocarps. Anal border with small crenulations.

Gonads.—Not developed, but the body wall on either side is covered with 4 longitudinal rows of flattened, leaf-shaped endocarps, their free and tapering ends directed posteriorly toward the atrial opening. The shape of these endocarps and their arrangement suggests that they are precursors of polycarps, since endocarps of a purely "packing" function are of more irregular shape and arrangement.

Relations.—This species is apparently the counterpart in this genus of the *Pyura pachydermatina* type; the inverted condition is unique, as is the nature of the test. *P. attollens* is resembled in many ways, especially in the dorsal tubercle, but the lobes on the anal border form a particular point of difference.

Distribution.—According to Hartmeyer (1928): "all Malayan Archipelago, northwards to the Philippines, eastwards to Samoa, north-east and east Australia and south to Sydney." Also Cape Jaubert and Shark Bay, W.A.; therefore distribution may be summarized as north Australian.

(9) Polycarpa thelypanes (Sluiter)

Fig. 47

1904 *Styela thelypanes* Sluiter, p. 68, pl. VIII, figs. 17-19.

External characters.—Body more or less club-shaped, wider posteriorly. Apertures on short cylindrical siphons; branchial aperture anterior, terminal; atrial aperture two-thirds of the distance posteriorly, and directed posteriorly. Animal fixed by the whole of the left side. Specimens small, $\frac{3}{4}$ in. long, $\frac{1}{4}$ in. wide.

Test.—Thin and transparent in the region where it is fixed; the right side is thicker, opaque, with sparse shell and hydroid encrustations.

Mantle.—Moderately muscular; the membrane lining siphon is raised into rounded mounds; well spaced, bearing closely fitting, flat plates; these may take the place of spines.

Branchial tentacles.—Simple, fairly short, thick, 22 of varying sizes with occasional rudimentary tentacles interspersed.

Dorsal tubercle.—A fairly large, rounded cushion with U-shaped slit; opening directed anteriorly and both horns turned to the left.

Dorsal lamina.—A plain, smooth membrane, not very wide.

Branchial sac.—With fairly narrow folds separated by wide spaces; the fourth fold flattens out posteriorly into an approximation of vessels. All folds run the length of the body parallel to one another; the oesophagus opens posteriorly. Longitudinal bars: D L 6 (10) 6 (18) 7 (13) 7 (15) 9 E. Four stigmata of oval, irregular size per mesh.

Alimentary canal (Fig. 47).—A single, open loop occupying the posterior half of the body. Oesophagus short, stomach short, spindle-shaped, internal plications showing through; intestine running anteriorly for some distance, then turning posteriorly to the anus, just anterior to the level of its origin from the stomach. Anal border folded back, with 8 well-marked lobes, which are sometimes indented.

Gonads (Fig. 47).—Small, rod-shaped gonads scattered in 2 or 3 irregular rows all over the body wall (except in the posterior region occupied by the intestine on the left). The ovaries form a solid covering over the testes.

Distribution.—Taken from Japanese oyster (*O. gigas*) trays in Oyster Harbour, Albany, W.A.; in view of this isolation from previous record at Sulu Archipelago (Sluiter), it may have been introduced with the oysters, which were brought from Japan.

(10) Polycarpa intestinata, sp. nov.

Figs. 48, 49

External characters.—Body large, rounded, $3\frac{1}{2}$ in. long, 3 in. wide; blackish grey colour. Both apertures sessile, the branchial terminal, the atrial one-third of the way down the dorsal aspect.

Test.—Thick, leathery, wrinkled externally, without encrustations.

Mantle.—Moderately muscular.

Branchial tentacles.—Simple, closely packed, rather long, about 40 in number, with smaller, very fine ones alternating.

Dorsal tubercle (Fig. 48).—Large, long, with a fleshy, blister-like appearance; it completely occupies the peritubercular area. Slit a long U-shape, slightly irregular, with horns turned out, and a few separate openings.

Dorsal lamina.—A broad, flat, plain membrane with longitudinal bars and stigmata extending right up to base of the membrane on either side.

Branchial sac.—Fairly broad folds. Longitudinal bars: D L 10 (25) 11 (33) 8 (33) 7 (19) 8 E. These bars are very closely approximated, and the stigmata are small, 6 in each mesh; a parastigmatic vessel is usually present.

Alimentary canal (Fig. 49).—Oriented horizontally in the posterior part of the body; forming a double loop, the first loop enclosing a large number of small, cylindrical, and crowded endocarps. The oesophagus is short, and the stomach more or less rectangular, opening into the intestine slightly to the right. The intestine in this region is of greater diameter than the stomach, but narrows as it turns anteriorly, then dorsally, forms a shallow loop, and turns anteriorly into the rectum. The anal border is fringed with long, finger-like lobes.

Gonads.—A double longitudinal row of closely packed, oval organs on either side in the centre of the body wall. The rest of the body wall is covered with tall, cylindrical endocarps.

Relations.—May be distinguished from all other species by the relatively large size of the intestine beyond the stomach, and the nature of the closely packed double row of gonads on either side of the body.

Distribution.—Port Jackson (one specimen only), N.S.W.

(11) Polycarpa capricornia, sp. nov.

Fig. 50

External characters.—Body wider posteriorly. Apertures on short siphon, the branchial anterior, the atrial one-third of the way along the dorsal aspect. Sometimes the test is produced posteriorly into roots and props.

Test.—Of medium thickness, tough, more or less smooth externally, with some wrinkles and furrows, and occasionally encrustations. Red anteriorly, fading slightly posteriorly.

Mantle.—Not very thick but very muscular. No spines in siphon.

Branchial tentacles.—Thirty long, simple tentacles, varying in length and alternating with additional shorter ones.

Dorsal tubercle (Fig. 50).—Completely occupying peritubercular area, but not complicated as in *P. attollens*.

Dorsal lamina.—A very narrow, smooth membrane, strongly ribbed.

Fig. 49.—*Polycarpa intestinata*. Alimentary canal and gonads on the left side of the body. (× 1). Fig. 50.—*P. capricornia*. Dorsal tubercle. (× 7.5). Fig. 51.—*P. sacciformis*. Alimentary canal. (× 1). Figs. 52, 53.—*P. rigida*. Dorsal tubercles from two individuals. (× 7.5). Fig. 54.—*P. rigida*. Alimentary canal. (× 1). Fig. 55.—*P. obtecta*. Left side of the body showing dorsal tubercle in the mid line anteriorly, the alimentary canal and enclosed endocarp, and gonads. (× 1). Figs. 56, 57.—*P. obtecta*. Dorsal tubercles from two further individuals. (× 5). Fig. 58.—*P. obscura*. Gonads, dorsal tubercle, alimentary canal, and enclosed endocarp. (× 1). Fig. 59.—*P. unilineata*. Body removed from the test. (× ½). Fig. 60.—*P. unilineata*. Dorsal tubercle shown in relation to two branchial tentacles. (× 7.5). Fig. 61.—*P. unilineata*. Alimentary canal and gonads on the left side of the body. (× 2.5).

Branchial sac.—Four folds on either side, broad but not overlapping. Transverse bars broad. Longitudinal vessels broad and flat: D L 2 (12) 3 (13) 3 (15) 4 (13) 6 E. Ten to 12 stigmata; a parastigmatic vessel usually present.

Alimentary canal.—Exactly similar to that in *P. attollens*, enclosing the same numerous and tall endocarps and anal border with finger-like, long lobes. Stomach rather egg-shaped, with internal plications.

Gonads.—Long, hermaphrodite organs scattered over the body wall but lying on their side, directed to the atriopore, and not upright as in *P. attollens.*

Endocarps.—Tall, cylindrical, lying in the alimentary loop and amongst the gonads.

Relations.—Very similar to *P. attollens* but differing in the nature of the dorsal tubercle and gonads.

Distribution.—Thursday I., Queensland.

(12) Polycarpa sacciformis Herdman

Fig. 51

1899 *P. sacciformis* Herdman, p. 48, pl. Cyn. XIX, figs. 1-4. See for distribution and description.

Only Herdman's type specimen was available—in a bad state of preservation. Only the alimentary canal could be distinguished.

External characters.—Similar to *P. aurata.*

Alimentary canal (Fig. 51).—Following a similar course to that found in *P. aurata.* The oesophagus is fairly short; the stomach is large and elliptical, transversely oriented, and finely plicated. The intestine turns anteriorly from the stomach, then runs transversely parallel to it and finally anteriorly.

(13) Polycarpa rigida Herdman

Figs. 52-54

1880-81 *Polycarpa rigida* Herdman, p. 76.
1880-81 *Polycarpa longisiphonica* Herdman, p. 77.
1882 *Polycarpa rigida* Herdman, p. 175, pl. XXIII, figs. 1-2.
1882 *Polycarpa longisiphonica* Herdman, p. 177, pl. XXIII, figs. 3-6.
1899 *Polycarpa rigida* Herdman, p. 47, pl. Cyn. XVIII, figs. 1 and 5-10.
1899 *Polycarpa longisiphonica* Herdman, p. 49, pl. Cyn. XIX, figs. 5, 6.

External characters.—From examination of numerous specimens there is seen a gradual gradation of *rigida*-type siphons and those typical of *P. longisiphonica.* In the absence of any internal structural differences in the body it seems unlikely that these are 2 separate species.

Test.—Thin, brittle, impregnated with sand. The branchial siphon is situated terminally on the oblong body and is of varying length. Its terminal portion is bare of sand. The atrial siphon, longer than the branchial siphon and with a similar bare area terminally, is situated one-third of the way down the dorsal margin.

Mantle.—Thin and adhering closely to the test; musculature feeble.

Branchial sac.—The differences (i.e. the only internal structural differences) recorded by Herdman (1882) for the branchial sac of *P. rigida* and *P. longisiphonica,* and based on relative thickness of transverse branchial bars, were on examination of the available specimens

found to be related to the size of the animals. There are 7-12 bars between the folds, and 10-20 bars on the folds, which are narrow. The stigmata number 5-8 in each mesh.

Dorsal lamina.—A narrow, smooth membrane.

Dorsal tubercle (Figs. 52, 53).—An oval or elliptical cushion with a simple, slit-like opening, either flask-shaped with one horn turned in, the other out, or V-shaped with both horns turned outward. There is always a large area between the peripharyngeal band and the tentacular band which is characteristic of the species.

Tentacles.—Of varying sizes, the larger simple, short, and stout, with smaller ones alternating.

Alimentary canal (Fig. 54).—A simple, wide-open loop occupying the posterior part of the body. The oesophagus is short; the stomach is oval, transversely oriented, internally pleated; the intestine ends in a lobed anus.

Gonads.—The numerous polycarps are buried in the body wall.

Relations.—Herdman (1906) has described a specimen, *P. manaarensis,* from Ceylon. I can detect no differences, from the description and figures he gives, between this species and *P. rigida,* and they may possibly be synonymous.

One specimen from Port Jackson was completely infested by a *Botrylloides* sp., but the test beneath this was still brittle with sand.

Distribution.—Port Stephens, Port Jackson, N.S.W.; Bass Strait. Usually in deep water, 20-40 fathoms.

(14) Polycarpa obtecta Traustedt

Figs. 55-57

1883 *Polycarpa obtecta* Traustedt, pp. 126, 134, pl. 5, figs. 7, 8; pl. 6, fig. 15.
1878 *?Polycarpa tumida* Heller, p. 103, pl. 2, fig. 15.
1884 *Polycarpa rugosa* von Drasche, p. 38, pl. 7, figs. 3, 4 (from Rio de Janeiro).
1898 *?Styela (Polycarpa) appropinquata* Sluiter, p. 18, pl. 1, figs. 19-21 (from La Tortuga I., Venezuela).
1898 *?Styela (Polycarpa) asiphonica* Sluiter, p. 17, pl. 1, figs. 16-18 (from Rio Hacha, Goajira).
1898 *Styela (Polycarpa) brevipedunculata* Sluiter, p. 15, pl. 1, fig. 12 (from Curaçao).
1898 *?Styela (Polycarpa) cartilaginea* Sluiter, p. 16, pl. 1, figs. 13-15 (Gairaca, Santa Marta).
1898 *?Styela (Polycarpa) friabilis* Sluiter, p. 13, pl. 1, fig. 11 (from Kingston, Jamaica).
1898 *Styela (Polycarpa) fuliginea* Sluiter, p. 12, pl. 1, fig. 10; pl. 3, fig. 45 (probably from near La Tortuga I., Venezuela).
1898 *Styela (Polycarpa) insulsa* Sluiter, p. 14, pl. 3, fig. 43 (from Los Testigos I.).
1898 *?Styela (Polycarpa) nivosa* Sluiter, p. 12, pl. 1, fig. 9; pl. 3, fig. 46 (from Gairaca, Santa Marta).

1898 *Styela* (*Polycarpa*) *obtecta* Sluiter, p. 11 (from Santa Marta, Colombia).
1898 *Styela* (*Polycarpa*) *seminuda* Sluiter, p. 19, pl. 2, figs. 22, 23 (from La Tortuga I., Venezuela).
1900 *Polycarpa multiphiala* Verrill, p. 592, pl. 9, fig. 7 (from Bermuda).
1902 *Polycarpa obtecta* Van Name, p. 386, pl. 57, figs. 88, 89; 92-4; pl. 63, figs. 140, 144; pl. 64, figs. 151, 153.
1908 *Polycarpa obtecta* Hartmeyer, p. 111.
1909-11 *Pandocia obtecta* Hartmeyer, p. 1364.
1918 *Pandocia obtecta* Van Name, p. 103.
1921 *Polycarpa obtecta* Van Name, p. 420, fig. 90.
1921 *?Styela* (*Polycarpa*) *appropinquata* Van Name, p. 486.
1921 *?Styela* (*Polycarpa*) *asiphonica* Van Name, p. 486.
1921 *Styela* (*Polycarpa*) *brevipedunculata* Van Name, p. 486.
1921 *?Styela* (*Polycarpa*) *cartilaginea* Van Name, p. 487.
1921 *?Styela* (*Polycarpa*) *friabilis* Van Name, p. 487 (= *P. spongiabilis?*).
1921 *Styela* (*Polycarpa*) *fuliginea* Van Name, p. 487.
1921 *Styela* (*Polycarpa*) *insulsa* Van Name, p. 487.
1921 *?Styela* (*Polycarpa*) *nivosa* Van Name, p. 487 (= *P. spongiabilis?*).
1921 *Styela* (*Polycarpa*) *seminuda* Van Name, p. 487.
1924 *Polycarpa obtecta* Van Name, p. 31.
1930 *Polycarpa obtecta* Van Name, p. 486, figs. 53, 54.
1932 *Polycarpa obtecta* Berrill, p. 78.
1935 *Polycarpa obtecta* Berrill, pt. 3, pp. 257, 270, fig. 3H.
1937 *Polycarpa obtecta* Plough and Jones, p. 101.
1945 *Polycarpa obtecta* Van Name, p. 257, fig. 156.

External characters.—Body more or less erect and rectangular in form, laterally flattened. Branchial opening terminal, atrial opening one-third of the distance along the dorsal surface. The siphons protrude only slightly to the exterior.

Test.—Not very thick, but gelatinous and covered with sand; slightly thickened basally where it is fixed. There are no tubercles or other protuberances on the test.

Mantle.—Fairly thin, typically with transverse fibres, which are not in bands. The internal siphons are distinct but with little musculature, there being only delicate circular muscle fibres. The mantle is brown in colour.

Branchial sac.—With 4 well-marked folds, each bearing 10-13 bars. There are 2 bars between folds except between the dorsal lamina and dorsal folds of each side, where there are no bars. There are 12-14 stigmata in transversely elongate meshes, and parastigmatic vessels are usually present. The longitudinal vessels are broad.

Dorsal lamina.—A narrow, flat, plain membrane with strong ribs on either side.

Dorsal tubercle (Figs. 55-57).—A small, simple, circular organ with a V-shaped slit, both horns being turned to the right. In one specimen there was also a transverse slit posterior to the rest of the tubercle (Fig. 56). In another specimen (Fig. 57) there is more complex coiling.

Tentacles.—Slender, filiform, usually fairly short, about 30 of fairly regular size, larger alternating with smaller ones; but there are frequent variations from this in specimens that differ in no other way.

Alimentary canal (Fig. 55).—Confined to the posterior end of the body. The oesophagus is of average length; the stomach elongate, spindle-shaped, transversely oriented and with internal longitudinal pleating. The intestine then forms a double loop. The first loop encloses a pear-shaped endocarp, drawn out to a point between the stomach and intestine (as in *P. pedunculata, maculata,* etc.). The second loop is open. The anus is fringed by 7 bidentate lobes, which are considerably longer on the dorsal margin or by 4 or 5 well-marked, entire lobes. There is considerable variation in the length of these lobes.

Gonads (Fig. 55).—There are about 30 hermaphrodite oval polycarps on the body wall on the right and a smaller number on the left of the animal. They are fairly large and often arranged more or less in 3 rows on either side of the body. In several immature specimens the gonads are reduced to about 13 on either side and embedded in the body wall or in endocarps. Testes lie on the body wall and are covered by ovarian tissue.

Endocarps.—Absent, apart from one enclosed by the gut, and those around the gonads.

Relations.—The variability of all features in these specimens suggests that rather more than one species is involved. But no apparent constant feature separates them. The alimentary canal, the branchial sac, and the externals are quite constant and similar to those of *Polycarpa moebii* Michaelsen and *P. spongiabilis* Traust. Specimens with a similar degree of development in the gonads do not show constancy in the formation of the dorsal tubercle and the number of tentacles. *P. moebii* is a closely related form, differing only in having shorter gonads, a larger number of branchial tentacles, and a different anal border, besides a greater musculature in the body wall. The relationship to *P. spongiabilis* is particularly close, the main distinction lying in the open apertures of the latter; but as the musculature around the siphons in this species is very weak it seems likely that on further examination the differences may be negligible.

Distribution.—Widely in West Indies; Bermuda, North Carolina, both coasts of Florida, south along the east coast of South America (see Van Name 1945). Also sparsely at Reevesby I., S.A., and Port Jackson, N.S.W.

(15) Polycarpa moebii Michaelsen

1905 *Polycarpa moebii* (part. Typus von der Bass Strait) Michaelsen, p. 104, pl. 4, figs. 6-8.

1928 *Polycarpa moebii* Michaelsen and Hartmeyer, p. 372.

External characters.—About 1½ in. in length, 1 in. in breadth, oval shape. Branchial and atrial apertures one-third of the body length apart.

Both apertures are sessile. The outer surface of the test is slightly irregular and there are sparse encrustations of sand and weed.

Test.—Thick and gelatinous.

Mantle.—Thick and muscular, with loose bands of longitudinal muscle surrounded by dense circular muscle fibres. In some of the specimens are numerous air pockets embedded in the mantle; this is not a universal feature, but when present the air bubbles raise blisters also on the inner walls of the mantle.

Branchial tentacles.—About 40, of varying length, with smaller intermediate ones interspersed.

Dorsal tubercle.—Usually a simple, U-shaped slit with right horn turned in.

Dorsal lamina.—Narrow and smooth, with strongly marked ribs on either side.

Branchial sac.—Similar to that of *Polycarpa obtecta* Traust., with similar numbers of broad longitudinal vessels; 9-12 stigmata in each mesh, though here parastigmatic vessels are not as common.

Alimentary canal.—Course and proportions as described for *Polycarpa obtecta* Traust., but anal border has more numerous and smaller lobes.

Gonads.—Numerous oval gonads, embedded in the body wall; testes covered by the ovary; more rounded than those of previous species.

Endocarps.—Only one, large, enclosed by the alimentary loop.

Relations.—Very similar to *Polycarpa obtecta* Traust. in every way except in the thickness of test and mantle, and the more numerous tentacles and less developed dorsal tubercle; the anal border also differs.

Distribution.—Generally around the south, east, and west of Australia; Trigg's I., Bunbury, Busselton, W.A.; Reevesby I., S.A.; Balnarring Beach, Vic.; Bass Strait; Bowen, Queensland. Not in great numbers.

(16) Polycarpa obscura Heller

Fig. 58

1878 *Polycarpa obscura* (part) Heller, p. 104, pl. 5, fig. 28.
1905 *Polycarpa obscura* Michaelsen, p. 107.
1919 *Polycarpa obscura* Hartmeyer, p. 45, pl. 1, figs. 19-21.
1928 *Polycarpa obscura* Michaelsen and Hartmeyer, p. 366.

External characters.—Almost quadrangular; siphons not very distinct. Branchial siphon anterior, atrial siphon about one-third of the body length along the dorsal surface.

Test.—Thin and parchment-like, but tough. Colour a dark blackish green.

Mantle.—Thin but muscular. Inner siphons not very distinct.

Branchial sac.—Tough, with well-marked internal longitudinal bars and 4 well-marked overlapping folds on either side of the body; 18-20 bars

on each fold and 4 or 5 between each fold, except dorsally, where there are no bars between the dorsal lamina and the most dorsal folds on either side of the body.

Endostyle.—A well-marked and deep groove.

Dorsal lamina.—A narrow, smooth membrane.

Dorsal tubercle (Fig. 58).—Fairly large, almost rectangular, set obliquely in the peritubercular area. The slit is a simple U shape, with inrolled horns.

Tentacles.—Some are long, the longest reaching almost to the mouth of the branchial siphon. These alternate with medium-sized tentacles, and between each two of these are smaller and very much finer tentacles. Total number 50 (not as numerous as stated by Hartmeyer 1919).

Alimentary canal (Fig. 58).—A double loop occupying the posterior part of the body. Oesophagus short, the stomach almost rectangular, transversely directed, smooth externally. The first loop encloses an oblong, large endocarp. The anal opening is fringed by small, regular lobes.

Gonads (Fig. 58).—Most distinctive, more or less elongate, with ducts directed toward the atrial opening in 3 more or less irregular rows on either side of the body. They are of very varying sizes, some very similar to the *Cnemidocarpa* type of gonad. Ovary in centre, testes densely packed about it; one duct. There are about 8-12 gonads in each row, i.e. 30 on either side of the body.

Endocarps.—Large, one enclosed in the alimentary loop and one smaller between the second loop and the stomach. Otherwise they are absent from the body wall.

Distribution.—Bass Strait; north Australia (Cape Jaubert); D'Entrecasteaux Channel, Tas.; Thursday I.; only rare specimens.

(17) Polycarpa unilineata, sp. nov.

Figs. 59-61

External characters.—A large, black specimen, 17 cm. long and 7 cm. broad. The posterior end of the test is produced into a short, thick, wrinkled stalk. The branchial siphon is terminal anteriorly; it is a long, wide cylinder and recurved ventrally and posteriorly. The atrial siphon is only about one-third of the length of the branchial and is situated at the base of the latter, i.e. about one-third of the total body length from the anterior end.

Test.—Black, leathery, tough, not very thick, slightly wrinkled. There are no foreign bodies attached. There are no spines or denticles lining the siphons.

Mantle (Fig. 59).—Thick and muscular. Internally the siphons are of similar dimensions to those found externally.

Branchial sac.—With 4 narrow folds and with a rudimentary fifth fold on the right-hand side between the dorsal lamina and the first fold. There is a flat, plain membrane between the dorsal lamina and the rudimentary fold; also on the left, between the dorsal lamina and the first fold. Between the rudimentary fold and the first fold on the left there are 3 bars anteriorly, but posteriorly, where the rudimentary fold flattens out, there are 8 longitudinal bars, so that here the arrangement is: D L 8 (10) 12 (16) 8 (18) 5 (12) 4 D (right-hand side). Eight to 12 stigmata per mesh.

Dorsal lamina.—A very smooth, fairly broad membrane.

Dorsal tubercle (Fig. 60).—Extending from the peripharyngeal band to the base of the tentacles. It is a flat cushion, with a slightly convoluted slit.

Tentacles.—Long and simple, 30, all of more or less the same length.

Alimentary canal (Fig. 61).—A simple loop. Oesophagus short, arising from about half-way down the dorsal surface. Stomach slightly enlarged, spindle-shaped, and inclined postero-ventrally. Gradually it narrows into the intestine, which forms an open loop extending ventrally and enclosing 3 large endocarps. The rectum extends anteriorly to the base of the atrial siphon and terminates in an anus with slightly crenulated border.

Gonads (Fig. 61).—A series of hermaphrodite, flat, pear-shaped organs arranged in a single row of 10 glands on either side of the body, around the atriophore. On the left they are ventral to the alimentary canal but do not extend posteriorly to the loop. There are minute rod-shaped spicules in the gonads and their ducts. The testicular lobes are, in each gland, rather sparsely distributed and number only about 12, joined together by ducts opening in a common duct just before the opening of the oviduct.

Distribution.—One specimen from Mackay, Queensland (6 fathoms).

Genus POLYANDROCARPA Michaelsen

Key to Species of the Genus Polyandrocarpa

1. Alimentary canal an open loop 2
   Alimentary canal closed 3
2. Distinct individuals connected by stolon . . . *P. pilella* Herd. (Van Name 1945)
   Individuals in a common test . . . . . *P. lapidosa* Herd.* (Herd. 1899)
3. A double row of gonads and well-marked anal lobes
   P. sabanillae Van Name (Van Name 1945)
   A single row of gonads; anal lobes indistinct or small 4
4. Pyloric caecum absent or vestigial 5
   Pyloric caecum well marked 6
5. More than 12 branchial bars on each fold, zooids in common test
   P. maxima Sluit. (Van Name 1945)
   Less than 12 bars on each branchial fold, zooids united by stolons
   P. zorritensis Van Name (Van Name 1945)

6. Smooth anus, long gonads, alimentary loop does not enclose an endocarp 7
   Minute anal lobes, short rounded gonads, alimentary loop encloses an endocarp
   P. australiensis, sp. nov.*
7. Two or 3 gonads on each side . . . . . *P. triggiensis*, sp. nov.*
   Seven or 8 gonads on each side . . . . . *P. colligata* Sluit. (Sluit. 1913)

Fig. 62.—*Polyandrocarpa triggiensis.* Gonads, alimentary canal, and endocarp. (× 7.5). Fig. 63.—*P. australiensis.* Alimentary canal and gonads on the left side of the body. (× 7.5). Fig. 64.—*P. australiensis.* External appearance. (× 3.5). Fig. 65.—*P. lapidosa.* Alimentary canal and gonads on the left side of the body. (× 7.5). Fig. 66.—*Oculinaria australis.* Dorsal tubercle. (× 7.5). Fig. 67.—*O. australis.* Alimentary canal. (× 3.5). Fig. 68.—*Symplegma viride.* Alimentary canal and gonads. (× 7.5). Fig. 69.—*S. viride.* Gonads from one side of the body. (× 10). Fig. 70.—*Stolonica australis.* Alimentary canal. (× 7.5). Fig. 71.—*Amphicarpa diptychos.* Alimentary canal and gonads on the left side of the body. (× 7.5). Fig. 72.—*A. elongata.* Alimentary canal and gonads. (× 7.5).

(1) Polyandrocarpa triggiensis, sp. nov.

Fig. 62

External characters.—A delicate, oval, elongate form, united by stolons, 1/8 in. long, 1/10 in. broad. Branchial aperture terminal, atrial aperture placed posteriorly at a distance of one-third of the body length; both on small protuberances of the test.

Test.—Thin, brittle, sand-encrusted, white, transparent.

Mantle.—Moderately muscular, whitish pink.

Branchial tentacles.—Closely packed, simple, of average length.

Dorsal tubercle.—A simple, transverse slit.

Dorsal lamina.—Smooth, narrow.

Branchial sac.—Rather shorter than the rest of the body, with 4 well-formed folds. Longitudinal bars: D L 0 (5) 1 (4) 1 (6) 1 (4) 0 E. Four to 6 elongate, rectangular stigmata in each mesh; parastigmatic vessels present.

Alimentary canal (Fig. 62).—A single narrow, closed loop. Oesophagus short, stomach egg-shaped with about 17 plications; a long, curved pyloric caecum lies in the alimentary loop and arises from the distal part of the stomach; intestine a narrow, uniform tube curving anteriorly and extending up to the anus, which is smooth and bordered with 2 lips. In some specimens the major portion of the alimentary canal, including the stomach, is posterior to the branchial sac.

Gonads (Fig. 62).—Long hermaphrodite organs, 2 on the left, 3 on the right; in some specimens there is 1 gonad only, on each side of the body. The 2 on the left are directed postero-ventrally, parallel to the rectum; the 3 on the right are oriented parallel to one another, also postero-ventrally, but they are shorter and confined to the posterior part of the body. In the gonads there is a strong tendency to loss of the double row of testicular lobes so that only one row remains, postero-lateral to the ovary, between the latter and the body wall. The testicular ducts curve around the side of the ovary and join the *vas deferens* on top (Fig. 62). There are as many as 6 testicular lobes in a row, double in some cases but generally single in the longer gonads; the double row of testicular lobes is more common on the shorter gonads.

Endocarps.—Few, lying on the body wall and between the gonads; large and rounded.

Distribution.—Under reef undercut, Trigg's I., W.A.

(2) Polyandrocarpa australiensis, sp. nov.

Figs. 63, 64

External characters.—Smaller, more round specimens than in the previous species; sometimes club-shaped; test posteriorly produced into a stalk of varying length and diameter, joining the stolon uniting the colony. Where the test meets the stolon there is often a large, hollow, oval enlargement (Fig. 64). Apertures sessile, both anterior, well separated on dorsal and ventral corners.

Test.—Thin, brittle, sand-encrusted or without encrustations; dark blackish grey.

Mantle.—Thin, weak musculature; of greyish colour.

Branchial tentacles.—Thirty, large, simple.

Dorsal tubercle.—A simple, transversely elliptical slit.

Dorsal lamina.—A plain-edged, broad membrane.

Branchial sac.—Rounded, turgid, with 4 folds. Longitudinal bars usually follow an irregular meandering course; delicate in the interspaces but better developed on the folds: D L 2 (7) 2 (7) 3 (8) 2 (5) 2 E. Four or 5 long, rectangular stigmata in each mesh. Usually no parastigmatic vessels.

Alimentary canal (Fig. 63).—A single closed loop, enclosing a rounded endocarp in the loop. Oesophagus very short, opening half-way down the branchial sac; stomach almost spherical and with 11 external folds; pyloric caecum large, curved (not as large as *Polyandrocarpa triggiensis*, sp. nov.). The intestine abruptly emerges from the stomach, curves around enclosing the endocarp, runs slightly posteriorly, then antero-dorsally to the atriophore. Anal border fringed by about 8 minute lobes.

Gonads (Fig. 63).—Oval hermaphrodite organs round the ventral margins of the body; ducts directed dorsally; 3 or 4 on the right, 1-3 on the left. They consist of a double row of testes (4 or 5 in each row) between the body wall and the ovary, the ducts curving round either side of the ovary to join above the ovarian ducts; the ovaries have 4 or 5 separate lobes joined by ducts.

Endocarps.—A few on the body wall; small.

Relations.—Most closely related to *P. zorritensis* Van Name, especially in the structure of longitudinal bars in the branchial sac; differs in the high development of the pyloric caecum.

Distribution.—Common along the west coast: Hamelin Bay, Rockingham, Fremantle, Rottnest, Trigg's I.

(3) Polyandrocarpa lapidosa Herdman

Fig. 65

1899 *Goodsiria lapidosa* Herdman, p. 99, pl. P—st. 111, figs. 1-12.

External characters.—Cauliflower-like colonies composed of tightly packed zooids with confluent tests. The external surface of the test impregnated with sand.

Branchial sac.—Rather long, with 4 narrow folds on either side. Very irregularly placed stigmata. Longitudinal bars: Right E 3 (4) 3 (6) 2 (5) 2 (5) 1 DL 1 etc.

Alimentary canal (Fig. 65).—The short oesophagus leads from the posterodorsal corner of the branchial sac; stomach oval and transversely oriented; intestine directed anteriorly; slightly S-bent. Anal border smooth. No external stomach folds.

Gonads.—Six elongate gonads on each side of the body, arranged in parallel rows and transversely, their ducts directed dorsally and composed of a double row of testes covered by ovary.

Distribution.—Port Jackson, N.S.W.

Genus OCULINARIA Gray

(1) Oculinaria australis Gray

Figs. 66, 67

1868 *Oculinaria australis* Gray, p. 564, 1 text figure.
1886 *Oculinaria australis* (sp. dub.) Herdman, p. 323.
1891 *Oculinaria australis* (sp. dub.) Herdman, p. 638.
1904 *Oculinaria australis* (sp. dub.) Michaelsen, p. 18.
1909 *Oculinaria australis* (sp. dub.) Hartmeyer, p. 1377.
1919 *Oculinaria australis* Hartmeyer, p. 385.
1928 *Oculinaria australis* Michaelsen and Hartmeyer, p. 346.

External characters.—Colonial forms with zooids closely packed in confluent tests, sometimes with their anterior ends more or less free and not as compact as *P. lapidosa*. From South Cottesloe, however, large massive, compact clumps, with about 3 zooids through the thickness of the colony, were collected. Both apertures anterior and fairly close together on small, wart-like external siphons. Zooids placed at different angles in the test so that all apertures reach the surface. Colonies massive rounded clumps, cylindrical or investing sticks, etc.

Test.—Impregnated with sand externally; with firm, jelly-like, continuous matrix internally.

Mantle.—Forms a hump between the siphons (reminiscent of some specimens of *Molgula sabulosa* Q. & G.). Internal siphons short and cylindrical. There is a strong ring of muscle around the branchial siphon but musculature elsewhere is negligible.

Branchial sac.—Very shortened dorsally, so that the longitudinal bars follow a more or less semicircular course: Right E (4) 4 (8) 4 (8) 4 (8) 0 DL 1 (10) 2 (8) 4 (8) 4 (6) 5. In the meshes are 2 or 3 fairly short, widely spaced stigmata; 6 stigmata lie in the region between the dorsal lamina and first fold.

Dorsal lamina.—Short, plain-edged, and fairly broad, strongly ribbed on the right-hand side.

Dorsal tubercle (Fig. 66).—A circular cushion lying in a small peritubercular area and having a symmetrical, posteriorly directed, U-shaped slit with laterally directed horns.

Tentacles.—Thirty-two of varying lengths in an irregular arrangement.

Alimentary canal (Fig. 67).—Oesophagus fairly short and leaving the branchial sac from half way along its length; stomach obliquely set, pyriform, wider distally, with about 18 spiral external folds but no caecum; intestine forming a fairly wide loop; rectum turning slightly anteriorly, and terminating in a 3-lobed anus with a serrated edge.

Gonads.—Five or 6 long, parallel gonads as in *P. lapidosa* Herdman, but present only on the right-hand side of the body; some specimens from Western Australia have only 2-4 gonads.

Endocarps.—Absent.

Relations.—Very close to *P. lapidosa* but shows differences in tentacles, longitudinal bars, folds on the stomach, body shape, course of the alimentary canal, arrangement of stigmata, and distribution of gonads.

Distribution. — Fremantle, Cockburn, Bunbury, Koombana Bay (Michaelsen and Hartmeyer); Wreck Bay, Cottesloe, Albany. Generally: west coast, Albany to Fremantle.

Genus SYMPLEGMA Herdman

(1) Symplegma viride Herdman f. brakenhielmi Michaelsen

Figs. 68, 69

1886 *Symplegma viride* Herdman, p. 144, pl. 18, figs. 7-14.
1902 *Symplegma viride* Van Name, p. 378, pl. 50, fig. 22.
1902 *Diandrocarpa botryllopsis* Van Name, p. 383, pl. 54, fig. 68; pl. 59, figs. 120, 121; pl. 60, fig. 123.
1903-1907 *Diandrocarpa botryllopsis* Seeliger, pp. 1145, 1146, fig. 214.
1904 *Diandrocarpa botryllopsis* Michaelsen, p. 43.
1904 *Diandrocarpa brakenhielmi* Michaelsen, p. 50.
1904 *Symplegma viride* Michaelsen, p. 23.
1918 *Symplegma viride* Michaelsen, p. 39.
1919 *Symplegma viride* Michaelsen, p. 101 (+ forma *brakenhielmi*, p. 105).
1921 *Symplegma viride* Van Name (+ *S. viride brakenhielmi*), pp. 404, 407, figs. 75, 76.
1925 *Symplegma viride* Grave, p. 225.
1927 *Symplegma viride* Grave, p. 218.
1928 *Symplegma viride* (+ *brakenhielmi*) Hartmeyer and Michaelsen, p. 358.
1930 *Symplegma viride* Van Name, p. 482, figs. 50, 51.
1932 *Symplegma viride* Berrill, pp. 78, 86, 88, figs. 5*b*, 5*d*, 5*e*.
1934 *Symplegma viride* Grave, p. 146.
1934 *Symplegma elegans* (part) Michaelsen, p. 154.
1935 *Symplegma viride* Berrill, pp. 257, 273, fig. 3*K*, pt. 4, p. 360, fig. 17*d*.
1935 *Symplegma viride* Grave, pp. 215 etc., pl. 1, fig. 2.
1937 *Symplegma viride* Grave, Galstoff, and Tertz, Ithaec. p. 560.
1937 *Symplegma viride* Plough and Jones, p. 101.
1940 *Symplegma viride* Berrill, pp. 272 ff., figs. 1-5.
1945 *Symplegma viride* Van Name, p. 232, pl. 18, fig. 2; figs. 139, 140C, 140D.

External characters.—Forming investing layers, or in some cases, having the zooids in lobes arising from an empty gelatinous base continuous with the test. Zooids closely packed in a single layer, and brightly coloured in red, cyclamen, brown, or orange; obliquely oriented in a transparent test. Branchial aperture placed slightly along the dorsal surface, anterior; atrial aperture one-third of the body length down the dorsal surface. Both apertures sessile.

Mantle.—Delicate; musculature negligible.

Branchial tentacles.—About 20, of varying sizes.

Branchial sac.—With 10-13 rows of stigmata, 4 longitudinal vessels and 4-6 stigmata in each mesh.

Alimentary canal (Fig. 68).—A double loop, both loops being usually open; oesophagus short; stomach rectangular, with 12-15 folds and a long,

curved pyloric caecum, longer in some specimens than others. Intestine extending anteriorly to one-half the body length, turning back on itself posteriorly and then anteriorly to the atriophore. Anal border smooth. Stomach varying in shape slightly. In specimens from Western Australia it may be more pear-shaped, and sometimes shorter. There is no constancy, however, in these variations and they may be due to different states of contraction of the body.

Gonads (Fig. 69).—Two-lobed testes, respectively anterior and posterior to the ovary. The testes vary in the size and number of lobes, at times being hardly branched at all. Developing eggs often present in the body cavity.

Distribution.—Red Sea, Indo-Malayan region, Philippines, Ceylon, Mauritius; in Australia—Thursday I., Townsville, Queensland; South Australia; Japanese oyster trays Albany, Middleton Beach (Albany), Hamelin Bay, Trigg's I., Shark Bay, Dirk Hartog, W.A.; also east coast of southern American States. Hence the distribution is, in the southern hemisphere, very general.

Genera DISTOMUS Gaertner and STOLONICA Lacaze-Duthiers and Delage

Key to Species of the Genera Distomus and Stolonica

1. Gonads in a single line below the endostyle, male, female, and hermaphrodite ..... *Stolonica australis* Mich.* (Mich. & Hart. 1928)
   Gonads scattered irregularly over the body wall 2
2. Male on left and female on right, no hermaphrodite organs ..... *Distomus* (North Atlantic and Mediterranean species)
   Scattered male and female and possibly hermaphrodite organs 3
3. Elongate gonads ..... *Amphicarpa elongata*, sp. nov.*
   Rounded gonads 4
4. No reduction of branchial folds ..... *Distomus zeitzi* Mich. (Mich. 1912)
   Reduction of branchial folds .. *Amphicarpa diptychos* Hart.* (Mich. & Hart. 1928)

Stolonica prolifera Sluiter and *Stolonica duploplicata* Sluiter may also be considered with the above species.

(1) Stolonica australis Michaelsen

Fig. 70

1927 *Stolonica australis* Michaelsen, p. 202.
1928 *Stolonica australis* Michaelsen and Hartmeyer, p. 352.

External characters.—More or less rectangular zooids, connected across their base by a stolon; sessile; covered with sand. The arrangement of zooids in a colony is rather diffuse and there is a considerable area between them. Apertures forming low, rounded cones. Branchial aperture antero-ventral, atrial antero-dorsal.

Mantle.—Very delicate and not muscular, with a brown pigment scattered throughout. The internal siphons are short cylinders, the atrial siphon lying one-third of the body length down the dorsal surface.

Branchial sac.—With 2 well-marked folds which flatten out posteriorly; 7 or 8 longitudinal bars on each fold, 2-4 between folds. Between the endostyle and the second fold are 3 longitudinal bars, but none between the dorsal lamina and the first fold. There are 4-6 elongate, rectangular, and regular stigmata per mesh.

Dorsal lamina.—A broad, plain membrane, ribbed on both sides.

Dorsal tubercle.—A regular oval, directed longitudinally.

Branchial tentacles.—Simple, of varying lengths but generally long and numbering about 50, alternating in size.

Alimentary canal (Fig. 70).—Short and broad, forming a simple loop. Oesophagus short, sharply cut off from the stomach, which is slightly wider at the pyloric end. Hartmeyer (1919) drew a direct relationship between the number of longitudinal bars in the branchial sac and the number of folds on the stomach. However, in this species, which has fewer branchial bars than *Amphicarpa diptychos* Hart., there are 20 folds in the stomach wall, while *A. diptychos* has, in specimens of this collection, only 18.

There is a short but thick, curved pyloric caecum. The first loop of the canal is very narrow and encloses 2 small endocarps. The rectum continues anteriorly and ends in a 2-lipped anus.

Gonads.—As described by Michaelsen (1928)—15 on the right and 11 on the left, in rows below the endostyle.

Distribution.—Albany, W.A. (Michaelsen); Spring Bay, Tas. (10-12 fathoms).

(2) Amphicarpa diptychos Hartmeyer

Fig. 71

1919 *Distomus diptychos* Hartmeyer, p. 87, pl. 2, fig. 48.
1922 *Amphicarpa diptycha* Michaelsen, p. 457.
1928 *Amphicarpa diptycha* Michaelsen and Hartmeyer, p. 357.

External characters.—Large, "cauliflower"-like, rounded colonies composed of closely packed conical zooids with rounded ends anteriorly; or closely packed around twigs. Apertures close together on the anterior end. The tests of the zooids are, however, complete and joined by stolons, so that the zooids may often be further apart and the colonies do not appear cauliflower-like.

Test.—Impregnated with sand.

Mantle.—A purple colour. There are particularly strong circular muscles around both siphons, forcing them together and forming a ridge around them. Internal siphons are of medium lengths and are very muscular.

Branchial sac.—With 2 well-marked folds on either side. Longitudinal bars: E 5 (8) 3 (11) 2 DL. The folds, as in *S. australis*, flatten out posteriorly. Stigmata number 3-5 in each mesh.

Dorsal lamina.—A broad, ribbed membrane.

Dorsal tubercle.—A long, oval slit.

Branchial tentacles.—Closely packed, with confluent bases, about 100, larger and smaller alternating.

Alimentary canal (Fig. 71).—A simple loop; oesophagus short; stomach rectangular, with 18 or 19 internal folds; intestine broad; rectum extending anteriorly and terminating in a smooth anal border. The loop is wider than that of *S. australis* and encloses 2 large endocarps. Between the latter there is a ligament passing over the stomach across to the intestine. Fixing the pole of the intestinal loop to the body wall there is a series of about 8 radiating ligaments. There is a short, narrow, curved caecum.

Gonads (Fig. 71).—Testes extend all around the dorso-ventral margin of the peribranchial cavity. They appear to be arranged in about 6 groups ventrally, fewer dorsally. The ovaries are disposed in a row along the ventral border on either side of the testes, and along the dorsal surface of the intestinal loop; they are darker and larger than the testes.

Endocarps.—These are found posterior and anterior to the intestine and between the ovaries.

Distribution.—Cape Jaubert, Shark Bay, Albany, W.A.; Anglesea, Vic.; D'Entrecasteaux Channel, Tas.

(3) Amphicarpa elongata, sp. nov.
Fig. 72

External characters.—Body rounded, fixed posteriorly by a short stalk; branchial aperture terminal, atrial one-third of the body length along the dorsal surface. Both apertures sessile.

Test.—Thin, leathery, red.

Mantle.—Moderately muscular.

Branchial tentacles.—About 20, simple, of varying sizes but none very long; laterally flattened.

Dorsal tubercle.—A circular cushion with a longitudinal slit.

Dorsal lamina.—A broad, plain-edged membrane.

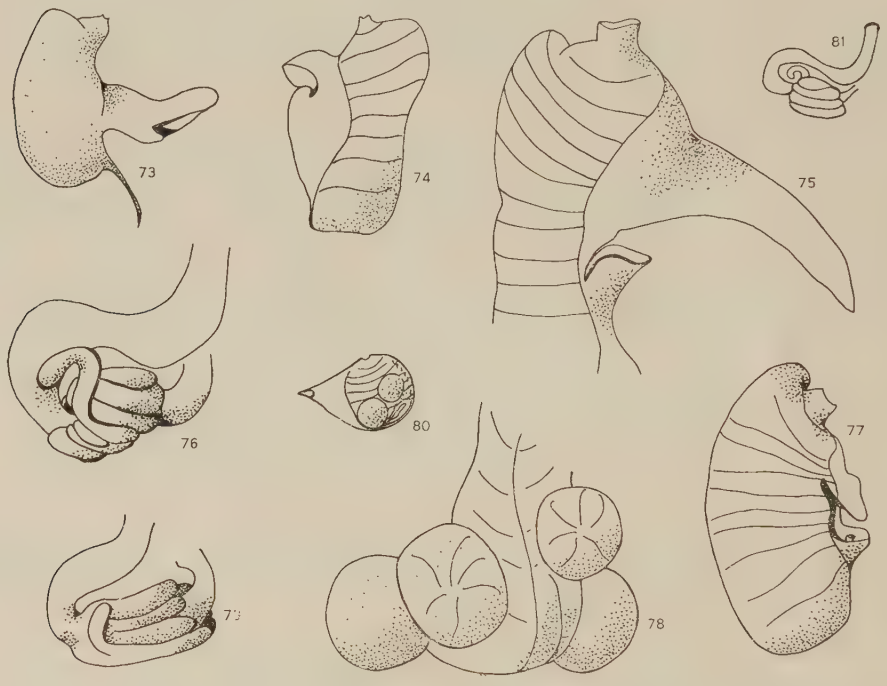
Branchial sac.—Three folds on each side; first fold well defined; second and third folds low, represented by a close approximation of bars, and fading out altogether posteriorly. Longitudinal bars: DL 6 (8) 3 (7) 3 (4) 3. Nine transverse vessels of one size; stigmata therefore long, 4 in each mesh; parastigmatic vessels present.

Alimentary canal (Fig. 72).—A single loop; oesophagus short and gradually widening into the pear-shaped stomach, which has numerous internal plications; intestine leaving stomach abruptly and looping around the long, curved pyloric caecum, running dorsally and then anteriorly to the atriophore, and ending in a two-lipped anus.

Gonads (Fig. 72).—All oval to elongate. Sexes separate; female organs 5-7 in a row on each side beneath the endostyle; male organs in 3 rows on either side of the body. All gonads embedded in endocarps.

Relations.—Amphicarpa elongata may be distinguished from other species by the shape and arrangement of the gonads, although the reduction of branchial folds posteriorly is a factor common to several species of this group.

Distribution.—Trigg's I., North Beach, W.A.



Figs. 73, 74.—*Botrylloides nigrum.* Two zooids, in different states of contraction, removed from the common test. (× 7.5). Fig. 75.—*B. magnicoecus.* Anterior portion of a zooid from the right side. (× 30). Fig. 76.—*B. magnicoecus.* Alimentary canal, showing stomach and pyloric caecum. (× 30). Fig. 77.—*B. leachii.* Whole zooid removed from the common test. (× 7.5). Fig. 78.—*B. leachii.* Posterior portion of a zooid from the ventral surface, showing ovaries and testes in brood pouches. (× 30). Fig. 79.—*B. leachii.* Stomach and portion of the alimentary canal. (× 30). Fig. 80.—*Botryllus schlosseri.* Zooid from the left side, showing position of ovaries and alimentary canal. (× 5.25). Fig. 81.—*B. schlosseri.* Alimentary canal. (× 15).

Genus BOTRYLLOIDES Edwards

Key to Species of the Genus Botrylloides

1. Long pyloric caecum . . . . . *B. magnicoecus* Hart.* (Mich. & Hart. 1928)
   Short pyloric caecum 2
2. Stomach longer than wide . . . . . *B. leachii* Sav.* (Mich. & Hart. 1928)
   Stomach wider than long 3

3. Testes and ovary considerably above intestine . *B. nigrum* Herd.* (Van Name 1945)
   Testes above ovary either side of intestine 4
4. Retort-shaped pyloric caecum .. .. *B. aureum* Sars. (Van Name 1945)
   Tubular pyloric caecum .. .. *B. diegenese* R. & F. (Van Name 1945)

(1) Botrylloides nigrum Herdman

Figs. 73, 74

1886 *Botrylloides nigrum* Herdman, p. 50, pl. 1, fig. 3; pl. 3, figs. 19-21.
1899 *Sarcobotrylloides jacksonianum* Herdman, p. 102, pl. Bot. II, figs. 1-8.
1899 *Sarcobotrylloides pannosum* Herdman, p. 105, pl. Bot. III, figs. 1-5.
1928 *Botryllus anceps* Michaelsen and Hartmeyer, pp. 335-6.
1945 *Botrylloides nigrum* Van Name, p. 227 (see for further synonymy).

Colony.—Irregular, fleshy, finger-like, flattened lobes; or investing layers, sometimes with small projections in form of lobes. Zooids arranged in closely packed and ramifying lobes. In the younger specimens the common cloacal opening is a small slit between the lobes. Blood vessels ramify in the test between the zooids. They are plentiful, some terminating in rounded ampullae, but at the surface of the test, between the zooids, ampullae are particularly plentiful and become elongate, cylindrical.

Zooids.—Varying in length, and set more or less vertically in the test. Atrial opening small, sometimes drawn out into a tube-like structure (see Figs. 73, 74). Colour red-orange-purple.

Tentacles.—About 32 of 3 orders; the largest lie perradially, and the medium-sized lie inter- and adradially; smaller tentacles are also interspersed. Four statocysts lie at the base of perradial tentacles.

Branchial sac.—There are 10-14 rows of stigmata (not as many as Michaelsen and Hartmeyer 1928 found for *B. leachii* in Australia, but covering the range of *B. nigrum* and the northern form of *B. leachii*). There are 3 internal longitudinal vessels, and the stigmata are arranged thus: 3 2 2 3 or 5 4 3 5 (in larger specimens).

Alimentary canal.—Varying in size and in the amount of body space it occupies. Stomach usually larger than in *Botrylloides magnicoecus* Hart., but smaller than in *Botrylloides leachii*. It is short, conical, rectangular, or rounded, and has 10 folds. The caecum is short, scarcely protruding beyond the stomach limits, but larger than in *B. leachii*.

Gonads.—Eggs are found postero-dorsally to the testes, which lie above the loop of the intestine on the left and more dorsally, just anterior to the stomach on the right, and have 4-18 lobes, arranged sometimes about a central lobe. There are developing eggs in the peribranchial cavity, and these occasionally push out the body wall into something like a brood pouch.

Distribution.—Malaya, New Zealand, South Africa (Cape of Good Hope), Mediterranean, north-west Europe, North Atlantic, and all around Australia; i.e. completely cosmopolitan.

(2) Botrylloides magnicoecus Hartmeyer

Figs. 75, 76

1928 *Botryllus magnicoecus* Michaelsen and Hartmeyer, p. 331.
1928 *Botryllus anceps* Michaelsen and Hartmeyer, p. 335, fig. 21.

Colonies.—Elongate, soft, fleshy lobes. The basal part of the test is free from zooids and consists only of jelly-like test. Zooids arranged in almost parallel double rows along the long axis of the colony. Vessels in the test are delicate, ramifying, terminating in small, round to oval ampullae between the rows of zooids; in the basal, zooid-free portion of the test they are larger and oval to elongate and more densely distributed.

Zooids.—Long, with small patches of pigment on either side of the endostyle ventrally, corresponding to each row of stigmata. Atriophore wide, with a particularly long upper lip (Fig. 75) and a patch of black pigment invariably at the base of this lip.

Tentacles.—Sixteen.

Branchial sac.—With 15-19 rows of stigmata; 3 or 4 stigmata in each mesh.

Alimentary canal (Fig. 76).—Smaller than that of *B. leachii.* Stomach short, rounded, with 9 or 10 rounded folds and a very long caecum curving over into the alimentary loop. Anus 2-lipped.

Gonads.—One or 2 ovaries anterior and slightly dorsal to the large, many-lobed testis just above the alimentary loop. Ovaries when larger extend out into brood pouch and change their position to one slightly ventral to the testis.

Relations.—I find this species is comparatively invariable both in the nature of the colony and the structure of the alimentary caecum, and in both characters quite distinctive from other forms. There is, however, a great variation in the number of rows of stigmata.

Distribution.—Not as common as *B. nigrum* or *B. leachii,* but occurring in Western Australia, South Australia, Tasmania, and New South Wales. This form seems to have the most southern extent of the group.

(3) Botrylloides leachii Savigny

Figs. 77-79

1899 *B. leptum* Herdman, p. 101, pl. Bot. I, figs. 5-13.
1928 *B. leachi,* Michaelsen and Hartmeyer, pp. 341-2.

Colonies.—Zooids in long, oval, or circular systems, well separated from each other, and opening into a central common cloaca. The zooids are more obliquely set than in other species of *Botrylloides.* The jelly-like test is thick and firm; vessels in the test are fairly few, terminating in long to oval ampullae; long, cylindrical ampullae are present, especially vertical to, and at, the surface.

Zooids.—Large. The atriophore is wide when the body is extended. The upper lip is only a little longer than the lower lip (Fig. 77).

Branchial sac.—Nine to 12 rows of stigmata; stigmata in each row: D L 6 4 3 4 E.

Tentacles.—Sixteen.

Alimentary canal.—Large, wide. Stomach long, conical to rectangular, with 8 folds and short caecum (Fig. 79).

Gonads.—Ovaries and testes when well developed are both enclosed in well-marked pouches; 1 or 2 ova lie dorsoposteriorly to the testes. The ovarian pouch arises anterior to the testes and in younger forms ova themselves are found there. Testicular lobes 11-20 (Fig. 78).

Relations.—Alimentary canal very like *Botrylloides nigrum* but differs in size of zooids, arrangement in the test, and the well-developed brood pouches.

Distribution.—Western Australia, South Australia, Victoria, and New South Wales; British Isles, Mediterranean, and Adriatic.

Genus BOTRYLLUS Gaertner

Key to Species of the Genus Botryllus

1. Four rows of stigmata 2
   Eight to 13 rows of stigmata 3
2. Atrial siphon posterior; rather short stomach . *B. primigenus* Oka (Van Name 1945)
   Atrial siphon anterior; longish stomach .. .. *B. tuberatus* Ritter (Van Name 1945)
3. Short pyloric caecum .. .. *B. schlosseri* Pall.* (Van Name 1945)
   Long pyloric caecum .. .. *B. planus* (Van Name) (Van Name 1945)

(1) Botryllus schlosseri (Pall.)

Figs. 80, 81

1932*a* *Psammobotrus purpureus* Oka, pp. 102-4.
1945 *Botryllus schlosseri*, Van Name, p. 220, pl. 9, fig. 4; pl. fig. 131 (and for further synonymy).

Colonies.—Large, rounded clumps or investing layers of test with closely packed small, rounded, orange zooids. Specimens from Green Pools and Hamelin Bay have the test completely impregnated with sand, as described by Oka (1932*a*) for *Psammobotrus purpureus* Oka. Blood ampullae in the test circular-oval.

Zooids.—Small, rounded, and arranged in circular systems. Atriophore not broken up into lips but protruding into a tube-like or conical protuberance (Fig. 80); anterior margin produced into a very small lip (as *B. tuberatus* Ritter, Van Name 1945). Branchial aperture anterior and sessile.

Tentacles.—Sixteen.

Branchial sac.—Seven or 8 rows stigmata; 3 internal bars on each side of the body. Three or 4 stigmata in each mesh.

Alimentary canal (Fig. 81).—Small, with long rectangular or spindle-shaped stomach. The caecum is fairly long—shorter than that of *B. magnicoecus* but longer than that of *B. leachii* and *B. nigrum*. The intestine, forming the loop of the alimentary canal, is, owing to the shortness of the body, almost horizontal. Anus 2-lipped. Eight to 10 stomach folds.

Gonads.—From the specimens examined it appears that the male and female gonads ripen at different times. In certain specimens there are 2 or 3 large eggs dorsal and anterior to diffuse testes having perhaps a central solid core. In other specimens the testis is rosette-shaped, with 5-9 lobes, and developing eggs are present in the peribranchial cavity.

Relations.—This species is very similar to *Botrylloides nigrum*, but the zooid is smaller, there are fewer rows of stigmata, a tubular atriophore, and a longer caecum.

Using Oka's description, there are no distinctions between the sandy specimens collected from Hamelin Bay and Green Pools in Western Australia and the specimens described (Oka 1932*a*) as *Psammobotrus purpureus*. The zooids of the sandy form are usually smaller than others but in all other characters they are identical, and the size of the zooids may be a direct result of the inclusion of sand in the test. There seems to be no justification for inclusion of the specimens in a new genus.

Distribution.—Fremantle, Hamelin Bay, Green Pools, W.A.; North and South America; New Zealand.

Family **PYURIDAE**

Genus PYURA Molina

Key to Species of the Genus Pyura

1. Body always bolteniform; with 6 branchial folds 2
   Body usually not bolteniform; not always with 6 branchial folds 8
2. Without calcareous bodies .. .. *P. legumen* (Lesson) (Herd. 1882)
   With calcareous bodies 3
3. Calcareous bodies in the test 4
   Calcareous bodies in the mantle only 7
4. Dumbbell-shaped spicules only present 5
   Dumbbell-shaped and stellate spicules present 6
5. Lobed anal border
   P. pachydermatina (Herd.) var. *intermedia* (Herd.)* (Mich. & Hart. 1928)
   Fringed anal border .. *P. pachydermatina* (Herd.) var. *gibbosa* Herd. (Herd. 1891)
   Smooth anal border .. .. *P. pachydermatina* var. *typica* (Herd.) (Brewin 1946)
6. Small stellate spicules only .. .. .. *P. australis* (Q. & G.)* (Mich. & Hart. 1928)
   Large stellate spicules and rod-shaped spicules . *P. spinifera* (Q. & G.)* (Mich. 1905)
7. Lobed anal border .. .. *P. ostreophila* Mich. (Mich. & Hart. 1928)
   Smooth anal border .. .. *P. australiensis* (Carter) (Mich. & Hart. 1928)
8. Stigmata arranged in rows only in the centre of the branchial sac
   P. rosea (Sluit.) (Sluit. 1887)
   Stigmata arranged regularly in rows in the whole of the sac 9

9. Six or fewer folds in the branchial sac 10
   More than 6 folds in the branchial sac 30
10. Gonads arranged in a circle, ducts directed to the centre
   P. polycarpa (Sluit.) (Sluit. 1904)
   Gonoducts directed toward the atriopore 11
11. Very short dorsal lamina, without languets in the adult
   P. stolonifera Heller* (Mich. & Hart. 1928)
   With well-marked languets 12
12. With slender biramous dorsal languets . . . . . *P. lanka* (Herd.) (Herd. 1906)
   Without slender biramous dorsal languets 13
13. Round stigmata . . . . . *P. trita* (Sluit.) (Mich. 1924)
   Elongate or rectangular stigmata 14
14. With fine, silky threads on the test . . . . . *P. formosa* (Herd.) (Herd. 1882)
   Without fine, silky spines on the test 15
15. With short, irregular, finger-like processes from the test 16
   Without short, irregular, finger-like processes on the test 18
16. With hermaphrodite gonads 17
   With block-shaped ovaries; testes separate and ramifying in the body wall
   P. leeuwinia, sp. nov.*
17. With long spines in the siphon . . . . . *P. pulla* (Sluit.) (Brewin 1946)
   With scales in the siphon . . . . . *P. multiradicata* (Herd.) (Herd. 1899)
18. Long bristle-like siphonal spicules 19
   Without long bristle-like siphonal spicules 21
19. Shortened dorsal lamina . . . . . *P. albanyensis* Mich. (Mich. & Hart. 1928)
   Dorsal lamina not shortened 20
20. Anus smooth . . . . . *P. jacatrensis* (Sluit.)* (Mich. & Hart. 1928)
   Anus lobed . . . . . *P. vittata* (Stimps.) (Oka 1935)
21. Simply pinnate tentacles . . . . . *P. fissa* (Herd.) (Sluit. 1904)
   With doubly compound tentacles 22
22. Without parastigmatic vessels in the branchial sac
   P. cerebriformis (Herd.) (Sluit. 1904)
   With parastigmatic vessels in the branchial sac 23
23. With thick, tough test† 24
   With thin, leathery test† 26
24. With smooth or sulcated test† 25
   With wrinkled test† . . . . . *P. michaelseni* (Oka) (Oka 1935)
25. With sulcations† . . . . . *P. plicata*, sp. nov.*
   Without sulcations† . . . . . *P. japonica* (Traust.) (Traust. 1885)
26. With spines lining the siphons 27
   Without spines lining the siphons 28
27. With rounded spines in the siphons . . . . . *P. arenosa* (Herd.) (Herd. 1882)
   With flattened, scale-like spines in the siphons . *P. aripuensis* (Herd.) (Herd. 1906)
28. With a wide intestinal loop 29
   With a narrow intestinal loop . . . . . *P. laevigata* Heller (Heller 1878)
29. Test sandy† . . . . . *P. molguloides* (Herd.)* (Herd. 1899)
   Test free from sand† . . . . . *P. arcuata* Heller (Heller 1878)
30. Test covered with short, radially branched spines . *P. hilgendorfi* Traust. (Oka 1935)
   Test without spines externally 31
31. Twelve to 15 folds in the branchial sac 32
   Seven to 9 folds in the branchial sac 34

† Distinguishing characters based on external differences, which may be unreliable as specific characters, but which have been adopted, after Herdman (1891*a*), in the absence of more complete descriptions.

32. With wart-like knobs on the test 33
Without any protruberances on the test . . . . . *P. comma* (Hart.) (Hart. 1906)
33. Globular processes on the test . . . . . *P. dumosa* (Stimps.) (Herd. 1899)
Ovate processes on the test . . . . . *P. roretzi* (von Drasche) (Oka 1935)
34. With a cancellous layer of test 35
Without a cancellous layer of test 36
35. With rampart-like elevations around the siphons *P. cancellata* Brewin (Brewin 1948)
Without rampart-like elevations around the siphons *P. carnea* Brewin (Brewin 1948)
36. With scale-like siphonal spines . . . . . *P. irregularis* (Herd.)* (Herd. 1882)
With conical siphonal spines 37
37. With lobed anal opening . . . . . *P. rugata* Brewin (Brewin 1948)
With smooth anal opening 38
38. With small conical siphonal spines . . . . . *P. subuculata* (Sluit.)* (Brewin 1948)
With long, pointed siphonal spines . . . . . *P. suteri* Mich. (Brewin 1946)

Group PYURA PACHYDERMATINA (Herdman)

Michaelsen remarks on this group (1928), "Unsere Kenntnis von dieser Gruppe ist eine noch sehr unklare und verworrene" (p. 406).

From examination of specimens collected round the coast of Australia, and from a study of the literature, it would appear that there are 8 different forms belonging to the group, which has the following characters: bolteniform body, 6 branchial folds, alimentary canal forming a simple loop extending anteriorly, and calcareous bodies in the test (see Michaelsen 1928, p. 407). Further characteristics are the posterior branchial aperture, the anterior atrial aperture, and the stalk arising from the branchial aperture end so that the animal is standing "on its head".

Amongst the specimens examined there are 5 of these different forms, with distinct and invariable characters. Another form has been described by Michaelsen (1905, 1922, 1928) from New Zealand as "*P. pachydermatina*" and is characterized by having a smooth anal border without lobes.

Herdman's original type† also came from New Zealand; he did not, however, observe the anal border and confused the specimens from the Challenger Expedition with some from Tasmania which were in the British Museum. He later confused it again with specimens he obtained from New South Wales in the collection of the Australian Museum. The specimens in the Australian Museum identified by Herdman as *P. pachydermatina* are identical with the form found on the coast of New South Wales and extending down to Tasmania, described here as *P. pachydermatina* var. *intermedia*, with a lobed anal border. Michaelsen's speci-

† The author is indebted to Miss B. Brewin of the University of Otago for the information that the New South Wales form does not occur in the South Island of New Zealand; thus Michaelsen's specimens may be identical with the type of the species and the only form occurring in the South Island, instead of, as had been thought, a second form present in the New Zealand area.

mens with the smooth anal border are probably identical with Herdman's original type, and perhaps also with *Cynthia lutea* Sluit., and should be known as *P. pachydermatina* var. *typica;* they do not seem to justify separation into species, since all characters including the spicules are identical.

Fig. 82.—*Pyura pachydermatina* var. *intermedia.* External appearance. (× ¼). Figs. 83, 84.—*P. pachydermatina* var. *intermedia.* Spicules in test. (× 125). Fig. 85.—*P. pachydermatina* var. *intermedia.* Siphonal spines. (× 125). Fig. 86.—*P. pachydermatina* var. *intermedia.* Dorsal tubercle. (× 15). Fig. 87.—*P. pachydermatina* var. *intermedia.* Anal border. (× 22.5). Figs. 88, 89.—*P. pachydermatina* var. *gibbosa.* Dorsal tubercles from two individuals. (× 15). Fig. 90.—*P. pachydermatina* var. *gibbosa.* Individual removed from the test. (× ½). Fig. 91.—*P. pachydermatina* var. *gibbosa.* Alimentary canal and gonads on the left side of the body. (× ¾). Fig. 92.—*P. australis* var. *typica.* External appearance. (× ¼). Fig. 93.—*P. australis* var. *typica.* Spicules in the test. (× 127). Fig. 94.—*P. australis* var. *typica.* Siphonal spines. (× 225). Fig. 95.—*P. australis* var. *typica.* Dorsal tubercle. (× 7.5). Fig. 96.—*P. australis* var. *typica.* Anal border. (× 22.5). Fig. 97.—*P. australis* var. *parvispinatis.* Spicule and spines from siphonal lining. (× 225). Fig. 98.—*P. australis* var. *parvispinatis.* Anal border. (× 9). Fig. 99.—*P. spinifera.* Spicules from invaginated test lining the siphons. (× 127). Fig. 100.—*P. spinifera.* Dorsal tubercle. (× 7.5).

The separation of species on the grounds of differences in the dorsal tubercle or on external characters is extremely undependable, owing to variation of these parts. Most dependable and constant characters are

available in the siphonal spicules found generally in the test and mantle; and in the border of the anal opening.

In view of this, and in an attempt to clear up the confusion existing in the group, a full description of all available forms is given.

(1) PYURA PACHYDERMATINA (Herdman) var. INTERMEDIA Herdman

Figs. 82-87

1845? *Boltenia pedunculata* (err. non Brugiere) Deshayes (Cuvier), pl. 124, figs. 1, 2, 2 aim Tafelerkl.
1873 *B. pedunculata* Hutton, p. 105.
1881 *B. pachydermatina* Herdman, p. 81. (Part.)
1882 *B. pachydermatina* Herdman, p. 89, pl. VII, figs. 6-8. (Part.)
1884 *B. pachydermatina* von Drasche, p. 370, pl. I, fig. 1; pl. II, figs. 1, 2.
1885 *B. pachydermatina* (part excl. Syn. von Drasche) Traustedt, p. 25.
1899 *B. pachydermatina* Herdman, p. 16, pl. Cyn. I, figs. 1-3.
1913 *B. pachydermatina* Herdman and Riddell, p. 875.
1922 *P. gibbosa* var. *intermedia* Michaelsen, p. 391.
1928 *P. gibbosa* Michaelsen and Hartmeyer, p. 410.

External characters.—The specimens vary in colour from bright orange to a greyish pink. The stalk is orange or cyclamen, transversely wrinkled, and 4-5 times the length of the body. The body is generally marked by longitudinal furrows between smooth ridges, about 3 furrows on each side of the body (Mich. 1922 *P. gibbosa* var. *intermedia*). The specimen from Wreck Bay has a row of about 4 conical pointed tubercles along each otherwise smooth and rounded ridge between the furrows (Fig. 82).

Stalk.—As described by Michaelsen (1928) for *P. gibbosa.*

Spicules.—Calcareous spicules are found in the test (Fig. 83, 84), especially in that part invaginated into the siphon. They are dumbbell-shaped, with 4 or 5 radiating knobs on either end and occasionally a knob along the shaft. Lining the siphon is also a mass of regularly arranged hooks (spines) (Fig. 85) directed anteriorly. They are slightly curved but lack the long base found in *P. australis* (Michaelsen 1928). No spicules were found in the mantle or branchial sac.

Test.—Thick and gelatinous but tough, with a tougher outer cuticle.

Mantle.—Muscular, but not very closely attached to the test. The inner siphons are protuberant, anteroposteriorly flattened, more or less triangular in cross section.

Branchial sac.—With 6 well-developed folds on either side of the body. On the folds are 12-14 longitudinal bars, and there are about 2 of these bars between the folds. Between the dorsal lamina and first fold there are 2 bars on the left, but these in some specimens disappear posteriorly where the thick transverse vessels are placed close together and give the appearance of a continuous membrane, on which appear a short row of languets similar to those on the lamina; on the right there are

similarly 2 bars and the appearance of a continuous membrane adjacent to the dorsal lamina (due to closely placed and wide transverse vessels). Herdman in his description of the Challenger specimens records 6 bars between the folds. This is reminiscent of the condition in *P. spinifera* Q. & G., syn. *P. tuberculata* Herdman. However, examination of Herdman's type specimens shows that he generally counts the basal bars on each fold as occurring in the interspace.

Dorsal lamina.—A row of rather long and closely placed languets.

Dorsal tubercle (Fig. 86).—Oval, round or irregular, rather large, with a closely convoluted slit that is more or less bilaterally symmetrical and probably based on the simple U-shaped slit with spiral horns.

Tentacles.—Rather long, bushy, compound, with a thick, laterally flattened stalk; 12-16 in number, with rudimentary tentacles alternating.

Alimentary canal.—This runs the same course as that usually found in other species of this group—a simple loop, narrow and extending well anteriorly, and enclosing a row of 5 block-like gonads that decrease in size posteriorly and are followed by numerous smaller ones. The fore part of the canal bears an arborescent liver with about 6 separate openings on either side of the canal. The border of the anal opening is particularly characteristic of the species, and consists of a series of rounded lobes of irregular sizes, distinct and in some cases fairly widely spaced (Fig. 87).

Gonads.—On the left-hand side of the body, as described above. On the right, 6-8 similarly formed and placed gonads lie along the ventral part of the body wall. On the dorsal border of the intestinal loop there is a series of block-shaped endocarps which in some specimens have been invaded by reproductory cells. Similarly the gonads themselves are often replaced with clear endocarp tissue.

This conforms with conditions found commonly in *Styela etheridgii*, in which the endocarps are large and often completely obliterated by gonads.

Distribution.—Eastern Australia; Coff's Harbour, Wreck Bay, Port Jackson, Port Hacking; Bass Strait.

(2) PYURA PACHYDERMATINA (Herdman) var. GIBBOSA Herdman

?1891 *Boltenia gibbosa* Herdman, p. 19. non Heller.

External characters.—Very similar in appearance to *P. pachydermatina*, but generally smaller, with a thinner and longer stalk. The test is marked with about 6 sharp ridges, similar to the specimen *P. pachydermatina* from Wreck Bay, but the conical tubercles along the ridges are not present.

Stalk.—Similar to that of *P. pachydermatina* var. *intermedia*, with a number of vessels branching off the 2 central vessels, in contrast to the more simplified condition in *P. australis*.

Spicules.—Similar to those of *P. pachydermatina* var. *intermedia.* Similar teeth also line the internal siphons.

Mantle and test.—As in *P. pachydermatina* var. *intermedia* (Fig. 90). In some larger specimens the outer layer of test peels off. This may be an explanation of the change in colour of the test, and may be an excretory phenomenon.

Branchial sac.—With 6 well-developed folds on either side of the body. The transverse bars are very wide. Between the dorsal lamina and the first fold on either side the wide transverse bars converge and form a continuous membrane, as is sometimes the case in *P. pachydermatina* var. *intermedia.* On the folds there are about 13 bars; between the folds there is always 1 only. (*P. pachydermatina* var. *intermedia* has more than 1.) Stigmata 3-6.

Dorsal lamina.—Consists of a row of languets of moderate length, shorter than those of *P. pachydermatina* var. *intermedia* and those of *P. australis.*

Dorsal tubercle (Figs. 88, 89).—This varies in complexity. It is usually circular, the slit having a rather convoluted horseshoe shape with the 2 horns spirally inrolled and the aperture to the right, but occasionally a more complicated and convoluted pattern is formed.

Tentacles.—Dense and compound, precisely similar to those of *P. pachydermatina* var. *intermedia.*

Alimentary canal (Fig. 91).—Generally similar to that of *P. pachydermatina;* the liver is arborescent. The rectum is not, however, turned anteriorly as in *P. pachydermatina* var. *intermedia.* The anal border is also distinctive and has a series of long, slender lobes with a long and fine fringe, giving it a matted appearance.

Gonads.—Similar in arrangement to, but more numerous than, those of *Pyura pachydermatina* var. *intermedia,* and numbering 10-12 on either side.

Endocarps.—Rectangular, present also along the dorsal edge of the intestinal loop, and often invaded by gonads.

Distribution.—Southern Australia—west side Walkerville, Flinders, Julia Percy I., Vic.; Victor Harbour, S.A.; Hamelin Bay, Cottesloe, Garden I., Rottnest I., Fremantle, W.A. Corresponds to *P. pachydermatina* var. *intermedia* in eastern Australia.

(3) PYURA AUSTRALIS (Quoy and Gaimard) var. TYPICA (Quoy and Gaimard)

Figs. 92-96

1834 *Ascidia australis* (part., material from "Port du Roi Georges") Quoy and Gaimard, p. 614.

?1834 *A. spinifera* (part, material from "Port du Roi Georges," falls solches vorhanden) Quoy and Gaimard, p. 615.

1891 *Boltenia? australis* (sq. inq.) (part) + *?B. spinifera* (sq. inq.) (part?) Herdman, p. 571.

1909 *P. australis* (sq. inq.) (part) + *?P. spinifera* (part?) Hartmeyer, pp. 1341, 1342.

1928 *P. australis* Michaelsen and Hartmeyer, p. 413.

External characters (Fig. 92).—Generally pinkish white or white in preserved specimens. The test is smoother than in either of the 2 preceding species. Shape oval, slightly laterally compressed, with a relatively thin stalk. The siphons protrude as in the 2 previous species and, in the younger specimens, these are the only protuberances on the test. In an older specimen from D'Entrecasteaux Channel there are several small conical protuberances on the test and around the apertures. Specimens from Flinders are more like *P. pachydermatina* externally and are marked by shallow furrows.

Stalk.—Rough but not wrinkled. In the type specimen it conforms entirely with the description given by Michaelsen and Hartmeyer (1928).

Spicules (Fig. 93).—Found especially in the invagination of the test into the siphons; they are short and radiating. Some preserve a more or less dumbbell shape, as in *P. pachydermatina*, but the branches along the shortened axis are longer and more numerous, and give the star-like appearance that is characteristic. They are found especially clustered alongside the blood vessels in the test. Spines (Fig. 94) are also borne on the portion of the test invaginated into the siphon (see Michaelsen and Hartmeyer 1928).

Mantle.—More delicate than that of *P. pachydermatina.*

Branchial sac.—Six folds each bearing 7-9 bars; 3 or 4 bars between folds. The area between the dorsal lamina and the first fold is greater here than in the 2 preceding species and there are 3 or 4 bars on either side. Six to 9 stigmata occur in each mesh.

Dorsal lamina.—Consisting of a row of languets of average length, shorter than those of *P. pachydermatina* var. *intermedia,* but longer than in *P. pachydermatina* var. *gibbosa.*

Dorsal tubercle (Fig. 95).—Simple, more or less circular or oval, with a horseshoe-shaped slit and spirally inrolled horns. The opening is directed anteriorly or to the right. The condition of the dorsal tubercle is here more simple than in *P. pachydermatina* (where it is most complex), and the more complicated patterns in the latter appear to be based on this form. In other features *P. australis* seems rather to have become more specialized than the 2 preceding varieties.

Tentacles.—Compound, bushy, numbering 12-14 of varying sizes.

Alimentary canal.—Following the usual course. The liver is similarly placed, although not as well developed as in the preceding species. The anal border (Fig. 96) has characteristically long lobes, flattened in the same plane as the radius of the anal opening, i.e. at right angles to the

lobes of the anal border in *P. pachydermatina*. They are also longer and more closely packed than in the latter species.

Gonads.—Similar distribution to that in other species; 7 or 8 on the right and 8-12 on the left. In specimens from Victoria the gonads along the right side are continuous with numerous dendritic processes. The condition of the gonads in this case approaches the condition in *Styela* and indicates that the distinction between *Styela* and *Cnemidocarpa* on the basis of dendritic and non-dendritic gonads is insufficient for generic distinction, especially in a group where variations in gonads are extremely common.

Distribution.—Geraldton, Cottesloe, Fremantle, Bunbury, Busselton, Albany, W.A.; Flinders, Vic.; north opening D'Entrecasteaux Channel, Tinderbox, Tas.

(4) PYURA AUSTRALIS (Quoy and Gaimard) var. PARVISPINATIS, var. nov.

Figs. 97, 98

External characters.—Similar to some specimens of *P. australis* var. *typica*; rather longer, less rounded than the specimen figured (Fig. 92), with longitudinal furrows and rounded ridges.

Test.—Colour whitish brown to pinkish brown.

Mantle.—Similar to var. *typica*. The spines lining the siphon, however, though of the same general shape, have a very much longer base; the spherical spicules are more sturdy and have a larger body and shorter arms (Fig. 97).

Branchial tentacles.—Compound but not very bushy; secondary branches very small, short (2 large tentacles with smaller alternating).

Dorsal tubercle.—A U-shaped slit, turned to the right and with both horns turned in (similar to *P. australis* var. *typica*).

Dorsal lamina.—With well-spaced, fairly long, thin languets, curved over.

Branchial sac.—Differing slightly from the previous species in the disposition of longitudinal bars: DL 1 (11) 1 (11) 1 (13) 1 (13) 1 (13) 1 (9) 1 E. Stigmata are long, rectangular, 8 per mesh; a parastigmatic vessel is usually present.

Alimentary canal.—Course as for the previously described variety; anal border, however, without the long, finger-like lobes; the rectal wall in the region of the anus is raised into internal folds which, externally, give the appearance of short sharp lobes, though actually the anal border is quite flat (Fig. 98).

Distribution.—Robb's Jetty, Fremantle, W.A.

(5) Pyura spinifera Quoy and Gaimard

Figs. 99, 100

?1834 *Ascidia spinifera* Quoy and Gaimard, p. 617.
1878 *Boltenia gibbosa* Heller, p. 109, pl. 6.
1891 *Boltenia tuberculata* Herdman, p. 571.
1891 *Boltenia spinifera* Herdman, p. 571.
1899 *Boltenia tuberculata* Herdman, p. 17, pl. Cyn. 2.
1899 *Boltenia gibbosa* Herdman, p. 19.
1905 *Boltenia spinifera* Michaelsen, p. 72, pl. iv, figs. 1, 2.

External characters.—The body is more or less oval or club-shaped and covered with knobs, otherwise the test is smooth. It has a very distinctive appearance and a short and thick stalk. Although Heller's figure of *P. gibbosa* is not very clear there are no doubts on the synonymy of the above forms, first proposed by Michaelsen (1905). He examined specimens of *B. tuberculata* (identified by Herdman) from the Australian Museum, and was able to compare them with Heller's type specimen.

Spicules (Fig. 99).—These occur in the test. Some are rod-shaped, others star-shaped but very much larger than those of *P. australis*. There may also be some dumbbell-shaped spicules.

Test.—Thick and tough.

Branchial sac.—Seventeen to 20 bars on each of the folds and 3 or 4 between. Between the dorsal lamina and the first fold there are as many as 8 internal longitudinal bars. Six to 8 stigmata.

Dorsal lamina.—Has moderate-sized languets as in *P. australis* and *P. pachydermatina* var. *gibbosa*.

Dorsal tubercle (Fig. 100).—Set in a peritubercular area slightly larger than in the 3 preceding species, and with spirally inrolled horns. The opening is directed anteriorly and to the right, with 2 small apertures above the inrolled horns.

Tentacles.—Numerous, 23 of larger size, plus rudimentary ones interspersed.

Alimentary canal.—Of the usual form. The anal border has lobes as in *P. pachydermatina*.

Gonads.—Also similar to those in the latter species.

Distribution.—Port Jackson, Bass Strait.

(6) Pyura multiradicata (Herdman)

Figs. 101, 102

1899 *Cynthia multiradicata* Herdman, p. 30, pl. Cyn. IX, figs. 1-5.
1899 *Cynthia cataphracta* Herdman, p. 31, pl. Cyn. XI, figs. 1-7.

External characters.—In addition to Herdman's type specimens, a small specimen (3 by 1.5 cm.) from Chinaman's Beach was available from the Australian Museum collection. There seems to be a great deal of variation in the position of the stalk in relation to the rest of the animal. This may have led Herdman to describe his 2 specimens as distinct species. How-

ever, the apertures always bear a similar relationship and are found on the dorsal surface, sessile, and one-third and two-thirds of the distance along the dorsal edge respectively. Neither Herdman's type *C. cataphracta* nor the specimen from Chinaman's Beach has the tubercle found on the test of *C. multiradicata* (type). The presence of a stalk in the three specimens available is a constant feature; other such features are the small but

Fig. 101.—*Pyura multiradicata.* Alimentary canal and gonads on the left side of the body. (× 1). Fig. 102.—*P. multiradicata.* Anal border. (× 7.5). Fig. 103.—*P. irregularis.* Siphonal spines. (× 125). Figs. 104-6.—*P. irregularis.* Dorsal tubercles from three separate individuals. (× 10). Fig. 107.—*P. irregularis.* Branchial tentacle. (× 10). Figs. 108, 109.—*P. irregularis.* Alimentary canal and gonads on the left side from two varying individuals. (× ½). Fig. 110.—*P. irregularis.* Anal border. (× 7.5). Fig. 111.—*P. jacatrensis.* Alimentary canal and gonads on the left side. (× ½). Fig. 112.—*P. stolonifera* (marine form). External appearance. (× ¼). Fig. 113.—*P. stolonifera* (estuarine form). External appearance. (× ¼). Fig. 114.—*P. stolonifera* (marine form). Dorsal tubercle. (× 15). Fig. 115.—*P. stolonifera* (estuarine form). Dorsal tubercle. (× 15). Fig. 116.—*P. stolonifera* (marine form). Alimentary canal and gonads on the left side. (× ½). Fig. 117.—*P. stolonifera* (estuarine form). Alimentary canal and gonads on the left side. (× ½). Figs. 118, 119.—*P. leeuwinia.* Dorsal tubercles of two individuals. (× 7.5). Fig. 120.—*P. leeuwinia.* Siphonal spines. (× 112). Fig. 121.—*P. leeuwinia.* Anal border. (× 7.5). Fig. 122.—*P. plicata.* Siphonal spines. (× 112).

strongly pointed papillae found surrounding the apertures and, when the latter are contracted, lying horizontally across them. Otherwise the test has a minutely granulated surface.

Spicules and spines.—Found in the lining of the siphons more externally are the distinctive spherical spicules described by Herdman for *Cynthia cataphracta* (Cyn. XI, Figs. 3, 4) but further down in the siphon are the minute, fimbriated scales previously described for *Cynthia multiradicata* (Cyn. IX, Fig. 5) and borne on the siphon lining.

Branchial sac.—With 6 low rounded folds on each side. These are closely packed with longitudinal bars—12-20 on each fold. In the wide area between the folds there are about 2 longitudinal bars, and the same number occur between the dorsal lamina and the first fold on either side. Six to 12 stigmata are present in each mesh.

Dorsal lamina.—Consisting of a series of rather long languets.

Dorsal tubercle.—Simple, cordate, with opening to one side.

Tentacles.—Much branched, 24, large and small alternating. Herdman has recorded only 12 for *C. cataphracta*, but from examination of the specimen there are seen to be the 24 present.

Alimentary canal (Fig. 101).—A simple loop; the terminal portion of the rectum turns anteriorly for a short distance. There is a double row of arborescent clumps of liver in the region of the stomach, which is otherwise not marked off from the rest of the alimentary canal. The anal border (Fig. 102) is slightly indented to form about 6 broad, low lobes, otherwise it is smooth. When contracted the border is curved back.

Gonads.—These angular masses mentioned by Herdman (for *C. cataphracta*) number about 12 on either side of the body, arranged in a double row, on the left in the intestinal loop. The duct can be clearly distinguished joining the consecutive masses in each row, and the 2 ducts unite near the atrial syphon.

Distribution.—Port Stephens; Port Jackson (Herdman), Chinaman's Beach (Port Jackson), N.S.W.

(7) Pyura molguloides (Herdman)

1899 *Cynthia molguloides* Herdman, p. 27, pl. Cyn. VII, figs. 4-10.

Only Herdman's type specimen of this species was available, and as this is in an extremely damaged condition further description is impossible. Found in Port Jackson, N.S.W.

(8) Pyura irregularis (Herdman)

Figs. 103-110

1882 *Cynthia irregularis* Herdman, p. 141, pl. XVI, figs. 10-12.
1880-1 *Cynthia irregularis* Herdman, p. 60.

External characters.—Small, wrinkled specimens, 4 cm. long by 3 cm. wide, deeply cleft between the 2 siphons. The branchial aperture is ter-

minal. The atrial aperture lies from one-half to one-third of the body length along the dorsal surface, being directed laterally and perhaps ventrally. The atrial siphon is about half the length of the branchial siphon.

Test.—Tough, leathery, transversely wrinkled, without any foreign bodies attached. In the siphon there are densely distributed cup-shaped and scale-like spines, with an anteriorly directed concavity (Fig. 103). Toward the base of the siphon these become sparser and eventually disappear.

Mantle.—Very muscular, and with small rod-shaped spicules in the siphonal region.

Branchial sac.—Seven widely separated folds on each side of the body. The seventh fold is small and rudimentary but is always present. There are 2 bars between the dorsal lamina and first fold on the left, and on the right a broad membrane invariably runs to the base of the first fold. Sixteen to 20 bars occur on each fold and 3 or 4 bars between folds. The transverse bars are of irregular widths. Stigmata are from 4 to 10 to the mesh; they are longer and more rectangular than those figured by Herdman—but this may be due to shrinkage in alcohol. The transverse vessels vary in width. Parastigmatic vessels are present.

Dorsal lamina.—Consisting of a row of rather long, tentacular languets.

Dorsal tubercle (Figs. 104-106).—Not quite as broken up as Herdman's figure indicates, but there were observed in the specimens examined several degrees of breaking off of different parts of the tubercle. The tubercle is situated in a very elongate and narrow peritubercular area which becomes even longer as the animal grows—perhaps owing to lengthening of the siphon. It is typified by a "blister"-like appearance in the upper part of the area and along the peripharyngeal band. Deeper down in the narrower portion of the area there is a simple U-shaped slit. In smaller specimens the anterior portion shows a conspicuous slit broken up into several parts (Fig. 104), but in larger forms this appears to be replaced by the blister-like structure (Figs. 105, 106). One specimen from Outer Harbour, South Australia, has not this blistered appearance, the tubercle being placed at the top of the long peritubercular area with a long, U-shaped slit and both horns turned to the right.

Tentacles.—Small, numbering from 12 to 18. They are not bushy and are only doubly compound, the secondary branches being extremely short and stumpy and giving an appearance of an almost simple pinnate condition, except in the specimen from South Australia, where the tentacles are very bushy. The main axis of the tentacles is very much flattened in the same plane as the radius of the aperture (Fig. 107).

Alimentary canal.—A simple loop, widely open. The oesophagus is long, but the stomach is not differentiated. There is an arborescent liver.

The rectal portion of the canal is sharply cut off from the rest of the intestine, is strongly muscular, and contracts terminally to the anus, which has 6-8 lobes (Fig. 110).

Gonads (Figs. 108, 109).—Enclosed by the alimentary loop on the left, and occupying a similar position on the postero-ventral part of the right body wall. They consist of a series of hermaphrodite glands joined by individual ducts to a common duct running along the body wall through the centre of the area they occupy, and opening into the atrial siphon. On the inner margin of each gland is a pad of endocarp into which the mature gonad would presumably extend. Larger specimens show a variation in the distribution of the gonads, and instead of their occupying the centre of the area enclosed by the canal, they are grouped in a double row around that area immediately inside the canal, with their duct running between the 2 rows. Similarly, on the right-hand side of the canal, they are arranged around the ventral posterior part of the body wall. In these larger forms the number has increased to 10 pairs on the left, and 8 on the right. The variation in arrangement of gonads may perhaps seem adequate grounds for separation of the 2 forms, but other typical features are quite constant —external characters, endocarps, anal border, dorsal tubercle, tentacles, siphonal spicules; also, the distribution of the 2 forms is the same, and they occur in association.

Endocarps.—Present also in blocks along both sides of the pre-rectal portion of the alimentary canal.

Distribution.—Port Jackson (Herdman); D'Entrecasteaux Channel, on scallop bank (5 fathoms); Outer Harbour (S.A.).

(9) Pyura jacatrensis (Sluiter)

Fig. 111

1890 *Cynthia jacatrensis* Sluiter, p. 331, pl. I, figs. 8-9.
1904 *Halocynthia jacatrensis* Sluiter, p. 47.
1913 *Tethyum* (*Pyura, Halocynthia*) *jacatrensis* Sluiter, p. 66, pl. 6, figs. 1-3.
1919 *Pyura jacatrensis* Hartmeyer, pl. 1, figs. 1-3.
1928 *Pyura jacatrensis* Michaelsen and Hartmeyer, p. 431.

External characters.—The specimens are very small—1.5-2 by 1-2 cm.; sometimes they are found in close association with *M. claudicans;* they are usually longer than broad. Branchial siphon terminal, atrial siphon one-third of the body-length down the dorsal surface. In this species both external siphons are conspicuous, and there is a fold of test around both siphons.

Test.—Wrinkled, leathery, and tough, with thick coating of sand except on siphons. On the portion invaginated into the siphons there are closely packed, long, spinous processes. The test is often (especially in closely packed specimens) produced posteriorly into a stalk.

Branchial tentacles.—There are 20 long tentacles, with primary and secondary branches of alternating length so that sometimes the tentacles are almost simply pinnate, at other times bushy. Smaller tentacles alternate with these 20 longer ones.

Branchial sac.—With 6 well-marked folds on either side, 12-14 bars on each fold and 3-4 between two consecutive folds. Between the dorsal lamina and the first fold on either side there are about 5 bars. This is not in agreement with previously described specimens, where there are, at least on one side of the dorsal lamina, no bars between the dorsal lamina and the first fold. The siphonal spicules, however, are quite characteristic of the species.

Dorsal lamina.—With very long languets with curled ends.

Dorsal tubercle.—A simple, horseshoe-shaped slit with inrolled horns, and the opening inclined slightly to the right.

Alimentary canal (Fig. 111).—A simple loop, transversely oriented in the posterior part of the body. The stomach is not cut off from the rest of the canal. There is an arborescent liver in the proximal portion. The loop then turns slightly anteriorly and the pole is anterior to the level of the anal opening. The anal border is smooth.

Gonads.—A single gonad occurs on either side, being broken up into about 9-12 parts along either side of a central duct. On the left the gonad is enclosed by the alimentary loop. The gonads are embedded on tall, sometimes lobed endocarps.

Endocarps.—Situated all around the alimentary canal and on the gonads.

Relations.—This species is very variable—especially as regards the tentacles. However, it has already been shown (cf. *P. irregularis*) that compound tentacles in this genus are a very variable character.

Distribution.—Malaya, Batavia, Celebes, Sulu Insel, Kei Insel, Cape Jaubert, Shark Bay, Trigg's I., Cottesloe, Fremantle, Albany—that is, from Malaya south along the west coast of Australia.

(10) Pyura stolonifera Heller

Figs. 112-117

1878 *Cynthia stolonifera* Heller, p. 10, pl. II, fig. 10.
1878 *Cynthia praeputialis* Heller, p. 12, pl. III, fig. 16; pl. IV, fig. 22.
1884 *Pyura stolonifera* von Drasche, vol. 48.
1885 *Cynthia praeputialis* Traustedt.
1899 *Cynthia praeputialis* Herdman, p. 27, pl. Cyn. VII, figs. 1-3.
1904*a* *Halocynthia vanhaffeni* Michaelsen, p. 197, pl. 10, fig. 13; pl. 12, fig. 44.
1904*a* *Cynthiopsis valdiviae* Michaelsen, p. 201, pl. 12, figs. 35-40.
1904*a* *Cynthiopsis herdmani* Michaelsen, p. 208, pl. 12, figs. 41-43.
1911 *Pyura stolonifera* Hartmeyer, p. 554, pl. 57, figs. 9, 10.
1912 *Pyura stolonifera* Hartmeyer, p. 246.
1915 *Pyura stolonifera* Michaelsen, p. 370.

1923 *Pyura stolonifera* Michaelsen, p. 50.
1927 *Pyura stolonifera* Michaelsen and Hartmeyer, p. 193.
1928 *Pyura stolonifera* f. *waia* Michaelsen and Hartmeyer, p. 433.

External characters.—There are 2 distinct environmental forms observable in this species as found in sandy estuarine regions and on rocky coastlines respectively. The first form is rounded, broader than long, covered with sand and with the posterior aspect produced into numerous long and filamentous roots, also coated with sand. The siphons are smooth and bare (Fig. 112). The second form, growing on rocky coastlines, is the typical cylindrical form described by Heller, with the basal part of the test solid and produced to a more or less variable extent to form a stalk of slightly less diameter than the body itself. The test in this case is not encrusted with sand, has a leathery exterior and usually a great deal of weed, especially *Ulva*, growing on it. The siphons in particular are covered with growths of hydroid and weed (Fig. 113). Some specimens from South Australia are like the estuarine forms of New South Wales in shape, but agree in all other features with the marine form.

Test.—Thick and gelatinous in cross section. Hard and leathery externally.

Branchial sac.—Sturdy, with 6 or 7 well-marked and overlapping folds. On the folds are about 10-20 bars, and between folds 3 or 4. Between the dorsal lamina and the first fold are about 8 longitudinal bars. Stigmata number 5-9.

Dorsal lamina.—In young forms this is represented by a row of short languets at the ends of the transverse vessels on the left-hand side of a plain and flat membrane. The elongate shape of the body in the cylindrical forms is such that the dorsal border is considerably shorter, and the dorsal lamina becomes, in some forms, practically non-existent. In the sandy broadened forms it is quite long. In all older specimens the languets disappear.

Dorsal tubercle.—This is different in the 2 forms. In the sandy specimens it is circular to oval with a very much convoluted slit (Fig. 115); but invariably cylindrical pillar-like specimens show a double spiral cone (Fig. 114).

Tentacles.—Compound, 8 large and 8 small alternating.

Alimentary canal.—A double loop—in young forms there is no space between the ascending and descending ramus but in older forms development of the gonads seems to push these apart, leaving a quite large space. The second loop is quite open (Fig. 116). The oesophagus is rather long, the gut thin, and in the region of the stomach there is an increase in width. Here also is a large and arborescent liver. The anal border is broken into a series of broad but shallow lobes.

Gonads.—It is on these that the 2 different varieties described here may eventually be separated. However, there is such a great deal of

variation that until further specimens, in all stages of development, can be examined it seems more suitable to maintain the 2 in the 1 group—i.e. sp. *stolonifera*, which may eventually be divided into the 2 ecological varieties described here.

In the sandy estuarine form there are 2 rows of gonads, which are block-shaped and lie between the limbs of the alimentary canal on the left and on the body wall on the right (Fig. 117) antero-ventrally. In the cylindrical forms there are the 2 rows of gonads on the right but on the left 1 row seems to have moved to the other side of the intestine so that there is a row in the first and second loop (Fig. 116).

Relations.—The marine form from the east Australian coast may be the same as Michaelsen's var. *typica* (1923) but it is difficult to understand how a var. *praeputialis* on the New South Wales coast would be identical with the South African variety when there is discontinuity around the Australian coast and the typical *"praeputialis"* form extends no further than Victor Harbour in South Australia. The nomenclature of the group is still very confused.

Distribution.—On the east coast from Cape Moreton, Queensland, to Spring Bay, Tas., and west to Outer Harbour, S.A. (found at Wilson's Promontory, Walkerville, Flinders, Vic.; and Outer Harbour).

(11) Pyura subuculata Sluiter

1900 *Cynthia subuculata* Sluiter, p. 27, pl. 5, figs. 4-7.
1922 *Pyura subuculata* Michaelsen, p. 406.
1948 *Pyura subuculata* Brewin, p. 129, fig. 6; pl. 9, figs. 3, 13*A*.

External characters.—Numbers of specimens grow closely together and average 1 in. in length and ½ in. in breadth; they are more or less oval-shaped and the posterior region is often produced into a short stalk; individuals of this species are found in close association with specimens of *Microcosmus claudicans* Sav. Brewin (1948) found specimens of this species with *Microcosmus kura* Brewin; this latter species has, later in this work, been synonymized with *M. claudicans* Sav.; therefore the association between the two above-mentioned species is evidently a common one. The apertures are on fairly short siphons, surrounded by small papillae protruding from the test; the branchial aperture is anterior, terminal, the atrial aperture half-way down the dorsal surface.

Test.—Orange, leathery, wrinkled, fairly thick and tough.

Mantle.—With very strong muscles radiating from the branchial siphon, and 2 bands, on either side from the atrial siphon, merging with the former; also external circular bands of muscle around the siphons. Lining the siphons are small, conical spines (see Brewin 1948).

Branchial tentacles.—Eighteen of varying sizes with small, rudimentary ones between. The tentacles are not very bushy, the primary branches being long, but the secondary branches very short.

Dorsal tubercle.—A U-shaped slit, opening turned to the right with both horns turned spirally in.

Dorsal lamina.—A row of closely placed tentacular languets, long and gently tapering.

Branchial sac.—A strong sac with 9 overlapping folds on each side of the body. Transverse vessels are wide. Longitudinal vessels: DL 2 (15) 1 (18) 1 (20) 1 (19) 1 (17) 1 (17) 1 (17) 1 (12) 1 (9) 6 E. Four to 6 stigmata in each mesh; parastigmatic vessels usually present.

Alimentary canal.—An open horizontal loop confined to the posterior part of the body and ending in a 2-lipped anus.

Gonads.—Nine pairs of gonad blocks, embedded in endocarps on either side of a gonoduct, and enclosed in the alimentary loop on the left side of the body; on the right a similar arrangement exists.

Relations.—Brewin (1946, 1948) has discussed the elevation of *Pyura subuculata* Sluiter var. *suteri* Michaelsen to specific status on the grounds of differences in branchial sac and gonads; it appears that there is also a difference in the length and shape of spines lining the siphons; these are usually a dependable specific character and here *Pyura suteri* Michaelsen and *Pyura subuculata* Sluiter have been considered as separate and distinct species. The present species has, however, more branchial folds than recorded for previously described specimens of *P. subuculata.*

Distribution.—New Zealand (Hauraki Gulf), Sumner, French Passage; Outer Harbour, Port Noarlunga, S.A.

(12) Pyura leeuwinia, sp. nov.

Figs. 118-121

External characters.—Two in. long, 1.5 in. broad. Tough, leathery specimens, closely packed together and firmly fixed in grooves in rocks etc. Usually found on rocky and rough, exposed coast. Shape irregular and the test produced into a series of pointed processes, variable in length, distribution, and density (thickest, longest, and most dense around the apertures), but generally serving to lock together individuals of the species and hold them firmly in the groove or ledge of rock in which they are found; posteriorly are root-like extensions of the test that have a similar function but are more irregular and branched and have not the circular diameter of the long processes on other parts of the test; or there may be a stalk. Apertures are usually both anterior, both on siphons that may be protected by spinous projections found especially in this area; the branchial aperture antero-ventral, the atrial antero-dorsal on a longer and curved siphon.

Test.—Thick, tough, leathery, and may be slightly wrinkled or smooth between the spines. Colour varying from creamish in protected places to dark blackish brown in exposed places; there are few growths on the

tests, but sometimes investing compound ascidians occur. There are spherical glassy spicules embedded in the test, especially thick near the surface.

Mantle.—Thick and very muscular. There are very small spines lining the siphon (Fig. 120).

Branchial tentacles.—Compound, 8 large alternating with 8 smaller; they are strong, on a long base with wide backing and are strongly curved.

Dorsal tubercle.—Large S-shaped slit on a more or less circular cushion, usually lying transversely but sometimes longitudinally (Figs. 118, 119).

Dorsal lamina.—Long with languets of average length.

Branchial sac.—Strong, with 6 folds on either side of the body. Longitudinal bars: DL 0 (13) 2 (18) 2 (16) 3 (13) 3 (11) 3 (9) 3. Transverse vessels wide; stigmata small, oval, 4-6 in each mesh; parastigmatic vessels sometimes present.

Alimentary canal.—A closed loop extending along the ventral margin of the left side of the body and ending in a hooded anus having about 14 well-marked regular lobes (Fig. 121).

Gonads.—Testes, orange or white, forming a thick coating in the body wall except behind ovaries and alimentary canal; ovaries divided into 6 or 7 block-shaped pairs enclosed in the alimentary loop on the left, and the same in a corresponding position on the right.

Relations.—This species is a common and unique form on the south-western Australian coast, especially where the coast is exposed and rocky. The internal structure is most closely allied to that in *Pyura pulla* (Sluiter), but the gonads and siphonal spines are distinctive. Brewin (1946) mentions sand grains incorporated in the test of *P. pulla;* these may be related to or identical with the spherical spicules in the test of this species.

Distribution.—Coast of Western Australia: Trigg's I. to Frenchmen's Bay, Albany.

(13) Pyura plicata, sp. nov.

Fig. 122

External characters.—A white specimen, fixed along the ventral surface; branchial aperture terminal, atrial half-way along dorsal surface, both apertures on short siphons. Test marked by longitudinal and parallel furrows, especially in the region of the siphons.

Test.—Pinkish white, gelatinous, thick.

Mantle.—Moderately muscular. Siphons lined with large, curved spines on a flat, scale-like base (Fig. 122).

Branchial tentacles.—Compound, bushy.

Dorsal tubercle.—A fairly large, simply U-shaped slit with inrolled horns, and opening directed anteriorly.

Dorsal lamina.—With well-formed tentacular languets.

Branchial sac.—Six folds on each side of the body; 2 or 3 bars between folds between the dorsal lamina and first fold; about 13 on each fold; 4-6 stigmata in each mesh; parastigmatic vessels usually present.

Alimentary canal.—A single narrow loop running around the ventral margin of the body and extending anteriorly; there is no stomach enlargement, as is often the case in this genus. The rectum turns anteriorly for a short distance and ends in a smooth-rimmed anus. There is an arborescent liver where the intestine first turns anteriorly.

Gonads.—Arranged alternately on either side of and close to a central duct on the left side, and in a corresponding position on the right side. About 6 gonad blocks on either side of the duct.

Distribution.—Hamelin Bay, W.A.

2. Genus HERDMANIA Lahille

(1) Herdmania momus (Savigny) var. grandis Heller

Figs. 123-126

1878 *Cynthia grandis* Heller, p. 97, pl. 5, fig. 26.
1882 *C. complanata* Herdman, p. 145, pl. 17, figs. 1-9.
1884 *Microcosmus julinii* von Drasche, p. 371, pl. 2, figs. 8-9; pl. 3, figs. 1-2.
1891 *Microcosmus julinii* + *M. draschi* + *Rhabdocynthia complanata* + *Cynthia grandis* Herdman, pp. 575, 577.
1905 *Halocynthia grandis* Michaelsen, p. 85.
1908 *Pyura pallida* f. *grandis* Michaelsen, p. 270.
1909 *Pyura pallida* f. *grandis* Hartmeyer, p. 1340.
1919 *P. momus* f. *complanata* + f. *grandis* Michaelsen, p. 54.
1919 *Pyura momus* Savigny (sp. ampla) Michaelsen, p. 30.
1928 *Pyura momus* Savigny f. *grandis* (Heller); Michaelsen and Hartmeyer, p. 441.

External characters.—This is a particularly large variety, varying considerably in shape according to the part of the test that is fixed to the substratum. Length 4-5 in.; breadth 3-4 in. Some specimens, usually the smaller ones, are fixed by the posterior part of their tests, but usually the basal portion of the test is that corresponding to the postero-ventral portion of the animal, and in this case the appearance is that of an organism of greater breadth than height. The external apertures are on broad, cylindrical siphons. In upright specimens the branchial siphon is anterior and terminal, but in other specimens the branchial aperture is about one-third of the body length along the dorsal surface and the atrial siphon about two-thirds of the body length. Where numbers of specimens are growing together there is a tendency to formation of a stalk. One specimen was found commensal on a crab.

Test.—Usually without foreign bodies attached, but occasionally lamellibranchs are found burrowing in, and shells and weeds are attached basally. In the type specimen it is thick and gelatinous, with a thin, leathery cuticle externally, the gelatinous part being impregnated with spicules. There are no spines in the lining of the siphons.

Mantle.—Strong and muscular, impregnated with calcareous spicules. The internal siphons are long, cylindrical, projecting at right angles to the long axis of the body.

Spicules.—As previously described by other authors (see Herdman 1899).

Branchial sac.—Also impregnated with spicules similar to those found in the test and mantle. There are from 10 to 13 overlapping folds on either side of the body; there are 20-30 bars on the folds and 4-6 longitudinal bars between the folds. Between the dorsal lamina and the first fold on either side are about 11 longitudinal bars. Three to 5 stigmata occur per mesh.

Dorsal lamina.—Composed of a single row of fairly long and closely placed languets.

Dorsal tubercle (Figs. 123-126).—Usually large and flattened, circular or oval, with a much convoluted slit, but in a few specimens (smaller ones, from Victoria and from Long Reef, near Sydney) the slit is of a horseshoe shape, with spirally inrolled horns.

Tentacles.—Long, much branched, 14-16, and of varying sizes.

Alimentary canal.—Usually rather obscured by a great mass of endocarp material impregnated with spicules and forming a matrix in which the gonads develop (see *Styela etheridgii*). It consists of a single and open loop, enclosing a gonad, lying on the left-hand side of the body. Proximally there is a compact and extensive liver around the stomach area that is not sharply cut off from the rest of the alimentary canal. The anal border is broken up into short but broad lobes of irregular sizes.

Gonads.—There is one large gonad on either side of the body, with duct directed toward the atrial opening. In fresh specimens or in mature forms the ovary, which forms the central mass, is usually cyclamen, having the brilliant orange and compact testicular lobes placed in clumps around the surface, but apparently without definite arrangement. Occasionally the testis completely covers the ovary. The nature of the anus, number of stigmata, etc., and the gonads distinguish this variety from var. *galei* and confirm classification into distinct varieties. In immature forms the gonad on the left is reduced to a mere coating to the inner wall of the ascending alimentary canal, embedded in the endocarp.

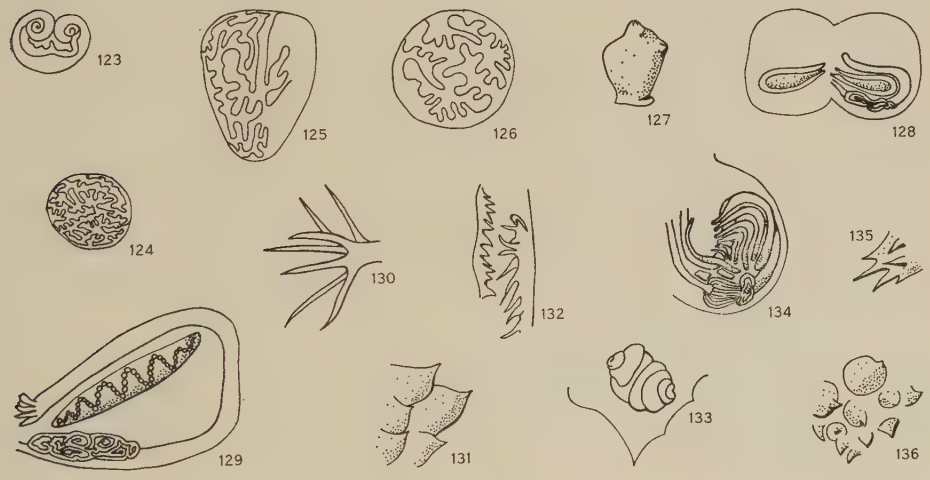
Distribution.—Common from Bowen, Queensland, to Port Phillip, Vic., in the east and from Albany to Geraldton in the west.

(2) Herdmania momus (Savigny) var. galei Michaelsen

Figs. 127, 128

1927 *Pyura momus* f. *galei* Michaelsen and Hartmeyer, p. 194.
1928 *P. momus* f. *galei* Michaelsen and Hartmeyer, p. 443.

External characters (Fig. 127).—This is a small, delicate species, the maximum size being 3 cm. broad and 4 cm. long. It is always upright, the branchial siphon being terminal and the atrial siphon one-third of the body length down the dorsal surface; both external siphons are situated on conical protuberances, the atrial being directed laterally.



Figs. 123, 124.—*Herdmania momus* var. *grandis*. Dorsal tubercles. (× 7.5). Figs. 125, 126.—*H. momus* var. *grandis*. Dorsal tubercles. (× 15). Fig. 127.—*H. momus* var. *galei*. External appearance. (× ¼). Fig. 128.—*H. momus* var. *galei*. Alimentary canal and gonads. (× ½). Fig. 129.—*H. momus* var. *curvata*. Alimentary canal and gonads on left side. (× 1). Fig. 130.—*Halocynthia hispida* var. *typica*. Hair from the test. (× 22.5). Fig. 131.—*H. hispida* var. *typica*. Siphonal spines. (× 22.5). Fig. 132.—*H. hispida* var. *typica*. Dorsal lamina. (× 10). Fig. 133.—*H. hispida* var. *typica*. Dorsal tubercle. (× 10). Fig. 134.—*H. hispida* var. *typica*. Alimentary canal and gonads on the left side of the body. (× ¼). Fig. 135.—*H. hispida* var. *crinitistellata*. Intermediate spine in the outer part of the siphon. (× 22.5). Fig. 136.—*H. hispida* var. *crinitistellata*. Siphonal spines from the middle part of the siphon. (× 22.5).

Test.—Smooth, gelatinous, thin but fairly turgid, white and semi-transparent. Some specimens from Tasmania showed a delicate red fleck in the test. There are no foreign bodies attached and only calcareous spicules of a form similar to var. *grandis* are present in the matrix of the test.

Mantle.—Delicate, also with spicules.

Branchial sac.—More delicate than in the previous variety, also with spicules. There are 6-8 folds on either side of the body, except in the specimens from Nelson's Bay, which have 11, the typical number for var. *grandis;* also 10-13 longitudinal bars on each fold and 1 between folds. Between the dorsal lamina and the first fold there is only 1 longitudinal bar, whereas var. *grandis* has numerous bars in this position. This form also, although smaller, has 6-8 stigmata in each mesh, whereas var. *grandis* has only 3-5.

Dorsal lamina.—Consisting of medium-sized languets in a single row.

Dorsal tubercle.—Of simple horseshoe shape, with horns occasionally turned in.

Tentacles.—Compound, 14-18, large and small alternating.

Alimentary canal.—As in var. *grandis,* enclosing the left gonad. There is in this case no endocarp material obscuring the alimentary canal. The anal border is smooth, without any indentations when extended, but when contracted showing minute lobes.

Gonads (Fig. 128).—There is 1 large, egg-shaped ovary on the right, and 1 also on the left, where it is enclosed by the alimentary loop. Around the ventral, anterior, and posterior limits of the ovary is a narrow band of testicle follicles forming a U shape.

Distribution. — In Western Australia: Broome, Shark Bay, Pt. Charles, Dirk Hartog; in eastern Australia: Bowen, Nelson's Bay, Port Stephens, and Tasmania. Thus distribution of this variety is the same as for var. *grandis.*

(3) Herdmania momus (Savigny) var. curvata, var. nov.

Fig. 129

External characters.—Diameter 3-5 cm. More or less circular and laterally compressed. Surface of test very irregular, with sponge and shell fragments attached, but mainly bare. The apertures are on short, broad, cylindrical siphons; the branchial terminal, and the atrial about half-way down the dorsal border. Posteriorly a short stalk may be produced.

Test.—Thin, soft, and cartilaginous.

Mantle.—Delicate and semi-transparent.

Branchial sac.—Delicate, with 10 or 11 well-marked folds; 3 longitudinal bars between the dorsal lamina and the first fold, and about 20 longitudinal bars on each fold; 3 between succeeding folds. Stigmata in each mesh 6-10, but interrupted by an intermediate longitudinal bar. Transverse vessels of 2 breadths, one being twice the breadth of the other and alternating with it.

Dorsal lamina.—Represented by closely placed languets of moderate length.

Dorsal tubercle.—Of a simple, horseshoe shape with spirally inrolled horns.

Alimentary canal.—A simple loop, almost closed and surrounding a more or less triangular area. The rectum does not turn anteriorly as in other forms of this species. The oesophagus is short, and the liver dense; the stomach is not cut off from the rest of the alimentary canal. The anal border has a series of long and irregular languets, which form a main distinguishing feature for the variety.

Gonads (Fig. 129).—Also characteristic and consisting of a cylindrical ovary on each side of the body; that on the left being inside the alimentary loop and parallel to the descending ramus. Superimposed on the surface of the ovary is a series of rosette-shaped testes arranged in a continuous and undulating line.

Distribution.—North West I., Capricorn Group, Queensland.

3. Genus HALOCYNTHIA Verrill

(1) Halocynthia hispida (Herdman) var. typica Herdman

Figs. 130-134

1880-1 *Cynthia hispida* Herdman, p. 61.
1882 *Cynthia hispida* Herdman, p. 146, pl. XV, figs. 1-4.

External characters.—The length varies from 3.5 to 8 cm. and the breadth from 3 to 7 cm. The animal is oval and regular, with the branchial siphon placed terminally on a rounded protuberance. The atrial siphon is one-third of the body length down the dorsal margin on a similar protuberance. A number of the specimens available were not fixed to any substratum, nor did they have any foreign bodies attached. Except in some cases a muddy coating was present.

Test.—Covered with minute, short but stout stalks, which distally break into 4-6 slender, pointed filaments, each sometimes twice the length of the stalk (Fig. 130). About the apertures these increase in length and diameter and form an area of dense, stiff, long hairs covered with spinous branches and smaller spines, which may have been derived from a shortening of the radiating branches of the shorter hairs covering the test. Fresh specimens are orange-coloured.

Mantle.—Strong and muscular, with very short siphons. These are lined with broad, low, conical, pointed denticles borne on long and rounded elevations continuous with the lobes about the aperture (Fig. 131). In the centre of these elevations, toward their base, the denticles are largest, thickest, and almost confluent, but they become progressively smaller at the sides and more externally. As on the spines there are, covering the denticles, minute protuberant spines.

Branchial sac.—With 9 or 10 folds on each side of the body; the ninth and tenth folds are always very small, with only 6 bars on each fold. On the larger folds there are 13-17 bars, and 3 or 4 bars occur between folds.

The meshes contain 5-7 stigmata. Between the dorsal lamina and the first fold are about 8 longitudinal bars.

Dorsal lamina.—Consisting of a double row of languets flanking a plain membrane. On the left-hand side the languets are long, on the right they are shorter (about one-half the length of the former) (Fig. 132).

Dorsal tubercle.—Invariable in all the specimens examined, and consisting of a double cone with a well-spaced spiral slit around each (Fig. 133).

Tentacles.—Only 8 in number, and consisting of a long, slender stalk with filamentous fringed branches. The length varies very little.

Alimentary canal (Fig. 134).—The oesophagus leaves the pharynx half-way down the dorsal surface and abruptly joins the stomach posteriorly. The stomach is conical, finely pleated, and tapers to the intestine where there is a circle of pyloric glands or liver. The intestine then forms a double loop and ends in the atrial siphon close to the origin of the oesophagus. The anal border is smooth and slightly rolled back.

Gonads (Fig. 134).—Seven cylindrical and more or less parallel ovaries curved at right angles occur on the left side, and 6 on the right side. On the left the most anterior follows the curve of the intestine, lying actually on the ascending limb and pole of the first loop and crossing the descending limb at right angles. The succeeding 5 lie within the curve, also crossing the descending limb at right angles, but the seventh is longer and follows the ascending limb of the second loop. Ducts extend along the upper surface and open toward the atrium. The testes form a continuous layer under the ovaries and cover the alimentary canal and adjacent body wall from the mid portion of the rectum to the region of the liver. The testicular ducts open in front of the oviducts.

Endocarps.—Present as slender, cylindrical projections between the gonads, and larger block-shaped projections between the stomach and lower part of the second loop.

Relations.—This species is closely related to *P. hilgendorfi* Traust., but differs in the shape and orientation of the alimentary canal and stomach; in the orientation and the number of gonads; in the number of tentacles; and in the shape of the dorsal tubercle.

Distribution.—D'Entrecasteaux Channel, Tas., in vast numbers (at about 5 fathoms); Bass Strait (38-40 fathoms) (Herdman).

(2) Halocynthia hispida (Herdman) var. crinitistellata Herdman

Figs. 135, 136

1899 *Cynthia crinitistellata* Herdman, sp. nov., p. 34, pl. Cyn. IX, figs. 6-7; X, fig. 13; XI, figs. 8-10.

1906 *Cynthia crinitistellata* Herdman, p. 313, pl. III, figs. 25-9.

External characters.—Several specimens from Port Jackson, in addition to Herdman's types, were examined. They were all of more or

less the same size, with the simple and branched spines described by Herdman placed on conical projections scattered sparsely over the surface. The spines around the apertures are more branched and dense and are arranged in tufts on conical projections on the test. Spines show generally a deviation from those of the previous species in that the larger spines along the shaft are arranged in circles at definite intervals, giving the appearance of jointing. The species is oval or spherical, despite the irregularities on the test. The fine down on the test described by Herdman is due to hairs similar to those of *P. hispida* var. *typica*. In younger forms these are not branched. Lining the siphon are densely placed denticles, similarly arranged to those in *P. hispida* var. *typica*, except that they are placed on about 4 distinct, rounded elevations between each 2 furrows (i.e. on the continuations of the lobes about the apertures). In the centre of these rounded elevations is a large denticle (Fig. 136). The denticles become progressively smaller further down, and extend almost to the base of the siphon. Anteriorly there is a gradual evolution from denticles to the elongate and branched spines; about the mouth this occurs by a lengthening of the shaft and the addition of secondary spines. An intermediate form is shown (Fig. 135) as a "branched" denticle. The denticles differ from those of *P. hispida* var. *typica* in that they arise from a broader, dome-shaped base but taper more gradually to a point which, therefore, appears to be longer and narrower. Their surface has not the small spines of the previously described species, but has a papillated appearance of dense, low, rounded elevations.

Branchial sac.—With 9 or 10 folds on each side. There are 6 bars between the dorsal lamina and the first fold and 3 or 4 bars between folds; also about 20 bars on each fold. Four to 7 stigmata occur per mesh.

Dorsal lamina.—Consisting of a double row of languets, as in *P. hispida* var. *typica*. These languets are numerous and short.

Dorsal tubercle.—A double spiral cone, as in *P. hispida* var. *typica*.

Alimentary canal, gonads, endocarps.—All identical with those in *P. hispida* var. *typica*.

Relations.—The only point of difference from *P. hispida* is the presence of long spines elsewhere on the body than about the mouth, and a slight variation in denticles in the siphon and on the spines. In a species which in other aspects is highly different from others of closely related genera, these differences seem to warrant a subspecific rather than a specific separation. Geographically, *P. crinitistellata* is a more northern form.

Distribution.—Karkopani (Herdman 1906), 6-9 fathoms; Port Jackson (1899).

4. Genus MICROCOSMUS Heller

KEY TO SPECIES OF THE GENUS MICROCOSMUS

1. Covered with long, branched, and echinated spines *M. spinifera* Herd.* (Herd. 1899)
   Not covered with long, branched, and echinated spines 2
2. Five overlapping folds . . . . . *M. oligophyllus* Heller (Heller 1878)
   More than 5 overlapping folds 3
3. Dorsal tubercle broken up into several parts . . . *M. arenaceus* Sluit. (Sluit. 1904)
   Dorsal tubercle not broken up 4
4. No longitudinal bars in the interspaces of branchial sac
   M. longitubis Herd. (Herd. 1882)
   With longitudinal bars in the interspaces of branchial sac 5
5. Eight to 10 folds in the branchial sac 6
   Seven or fewer folds in the branchial sac 7
6. Closed loop in alimentary canal . . . *M. claudicans* Sav.* (Mich. & Hart. 1928)
   Open loop in alimentary canal . . . . . *M. solanoides* Herd.* (Herd. 1899)
7. Two or 3 bars between folds 8
   Five or 6 bars between folds 12
8. With papillae on the branchial sac . . . . . *M. miniaceus* Sluit. (Sluit. 1900)
   Without papillae on the branchial sac 9
9. Pear-shaped stomach . . . . . *M. madagascarensis* Mich. (Mich. 1922)
   No stomach enlargement 10
10. Atrial aperture bilobed . . . . . *M. manaarensis* Herd. (Herd. 1906)
    Atrial aperture not bilobed 11
11. Conical spines of varying sizes . . . . . *M. nichollsi*, sp. nov.*
    Pointed, flattened spines of constant size . . . . . *M. stolonifera*, sp. nov.*
12. Conical processes in the siphon . . . . *M. helleri* Herd.* (Mich. & Hart. 1928)
    No conical processes in the siphon 13
13. Diaphragm in the branchial sac with crenulations *M. propinquus* Herd. (Herd. 1882)
    No diaphragm in the branchial sac 14
14. With horizontal membranes in the branchial sac . . *M. hirsutus* Sluit. (Sluit. 1913)
    Without horizontal membranes in the branchial sac
    M. polymorphus Heller (Heller 1878)

(1) MICROCOSMUS SPINIFERA Herdman

Figs. 137, 138

1899 *Cynthia spinifera* Herdman, p. 32, pl. Cyn. X, figs. 1-12.

External characters.—Small, globular, 1 in. long, 1 in. broad (maximum); sessile apertures moderately far apart, surrounded by especially long echinated spines; surface covered with these long, branched, and echinated spines. Siphon lining evaginated to form a continuous membrane or pocket around the base of the siphon. More externally in the lining are elongate spines, especially long externally and shorter internally. They are pointed, hollow, and slightly curved (Fig. 137).

Branchial sac.—With 18 bars on each fold, 2 or 3 between folds; otherwise as described by Herdman. Six folds on each side of the body; 1 longitudinal bar between dorsal lamina and first fold: DL 1 (25) 1 (19) 2 (26) 2 (29) 2 (30) 3 (19) 1 E; 6-8 stigmata per mesh.

Dorsal lamina.—A smooth-edged membrane.

Dorsal tubercle.—Small, with both horns turned in.

Tentacles.—Twelve large, 12 smaller, compound, very bushy.

Alimentary canal (Fig. 138).—A simple, narrow, and closed loop extending anteriorly, and enclosing a small area only at the top of the loop. Oesophagus of average length, stomach spindle-shaped, lying horizontally and internally pleated. The anus opens just anterior to the origin of the stomach and its margin is broken up into 3 large, rounded, smooth lobes.

Fig. 137.—*Microcosmus spinifera.* Siphonal spines. (× 125). Fig. 138.—*M. spinifera.* Alimentary canal and gonads on the left side of the body. (× ½). Fig. 139.—*M. claudicans.* External appearance of specimen from Queensland. (× ¼). Fig. 140.—*M. claudicans.* Siphonal spines. (× 125). Fig. 141.—*M. claudicans.* External appearance of specimen from Cronulla. (× ¼). Fig. 142.—*M. claudicans.* Dorsal tubercle. (× 7.5). Figs. 143, 144.—*M. claudicans.* Alimentary canal and gonads on the left side from two individuals. (× ½). Fig. 145.—*M. solanoides.* Siphonal spines. (× 125). Fig. 146.—*M. solanoides.* Siphon lining. (× 9). Fig. 147.—*M. solanoides.* Dorsal tubercle. (× 7.5). Fig. 148.—*M. solanoides.* Alimentary canal and gonads on the left side. (× ½). Fig. 149.—*M. nichollsi.* Siphonal spines. (× 125). Fig. 150.—*M. nichollsi.* Siphonal lining. (× 9). Fig. 151.—*M. nichollsi.* Animal removed from the test. (× ¼). Fig. 152.—*M. nichollsi.* Dorsal tubercle. (× 7.5). Fig. 153.—*M. nichollsi.* Alimentary canal and gonads on the left side. (× ½). Fig. 154.—*M. stolonifera.* Siphonal spines. (× 125). Fig. 155.—*M. stolonifera.* Dorsal tubercle. (× 7.5). Fig. 156.—*M. stolonifera.* Alimentary canal and gonads. (× ½). Fig. 157.—*M. helleri.* Alimentary canal and gonads on the left side. (× ½).

Gonads.—The large central ovary is curved and club-shaped, having the broad end lying in the loop of the gut and the posterior end curving

over the descending limb to lie alongside the prerectal portion. The testes are dense, surrounding the ovary and lying over adjacent portions of the gut (Fig. 138). On the right-hand side the gonad is similar.

Distribution.—Port Jackson, N.S.W.; Moreton Bay, Queensland.

(2) Microcosmus claudicans Savigny var. australis Herdman

Figs. 139-144

1878 *M. affinis* Heller, p. 98, pl. 1, fig. 6.
1899 *M. australis* + *M. ramsayi* + *M. affinis* Herdman, p. 23, pl. Cyn. 5: 25. Cyn. 6, figs. 1-5.
1908*a* *M. exasperatus* var. *typicus* (part material von Deutsch-Ostafrica) Michaelsen, p. 273.
1918 *M. exasperatus* var. *typica* Michaelsen, p. 11.
1928 *M. claudicans* var. *australis* Michaelsen and Hartmeyer, p. 404.
1948 *M. kura* Brewin, p. 136.

External characters.—Test usually of purple colour; specimens from Moreton Bay reddish brown. Size varying from minute specimens, which retain all the characteristics, but which appear to mature at about 3 cm. (height and width) to specimens of about 6 cm. square. Larger specimens may be longer than broad. Specimens growing close together in large clumps show a tendency to stalk formation by an extension of the posterior part of the test (Fig. 141). Apertures distant, on short siphons, although in two specimens from Green Island the siphons were longer (Fig. 139). Branchial siphon on ventral corner of the anterior end, and atrial siphon on the dorsal corner. There is a great deal of variation, however, in the length of the siphons and in the shape of the test.

Test.—Usually wrinkled in large specimens but may be smooth, and may be sparsely covered with weed. The siphons are lined with spines (Fig. 140) and tentacles, and have invaginations of the lining, which form large pockets (Herdman 1899); the fine tentacles are found on and around these pockets. Also in the tissue of test lining the siphons are found rod- and star-shaped calcareous spicules (see *P. australis*).

Branchial sac.—Eight or 9 folds on each side of the body, 1-3 longitudinal bars between folds; between the dorsal lamina and first fold there are only 1 or 2 bars. On the folds there are 15-20 bars, except on the folds adjacent to the endostyle, where there are only 8 or 9 bars. Four to 8 stigmata occur in each mesh. Larger specimens from Moreton Bay and further north have up to 11 folds on each side of the body.

Dorsal lamina.—A smooth membrane, not very broad.

Dorsal tubercle.—Invariably a double spiral cone (Fig. 142).

Tentacles.—Sixteen large and small alternating.

Alimentary canal (Figs. 143, 144).—A double loop, the first loop closed, the second open, and the descending portion of the second loop

lying against the anterior part of the canal. The stomach is not differentiated. The anal border is plain, slightly curved back. The liver is a dense, lamellated organ clumped at 1 or 2 irregular intervals along the anterior horizontal portion of the alimentary canal.

Gonads (Figs. 143, 144).—On the left these number 3—a short oval-shaped gonad in the anterior part of the first loop, a long, curved gonad starting on the first loop and crossing the intestine to lie in the second loop, with another smaller and oval-shaped gonad either anterior or posterior to it. Occasionally 2 or all of these gonads become continuous. On the right are 4 block-shaped gonads that may merge to 3 or fewer gonad masses. As in other species the gonads are embedded in endocarps, which may become completely obliterated, or the gonads may not be present, their place taken completely by endocarp. Any 1 or more of the gonads, especially on the left side of the body, may enlarge at the expense of the others, altering the relationship of one to the other; the position of the most posterior of the three on the left is anterior or posterior to the middle (and usually the largest) gonad, and is affected by the condition of the latter. Hence there is a great deal of variation in the appearance of the gonads. Testes usually are scattered over the surface of the ovaries in clumps, or may completely cover the ovaries.

Endocarps.—Fringing the alimentary canal in addition to surrounding the gonads.

Relations.—Brewin (1948) has described as new *M. kura;* this differs from *M. exasperatus* Heller in the number of coils in the dorsal tubercle and the average number of vessels between the folds. These differences are invalid since both are variable factors, and especially since there is great similarity in siphonal spicules and tentacles. Specimens from Moreton Bay and further north differ from the typical southern form in the increase in size and consequent increase in the number of branchial folds, in the difference in colour, and in the relatively small and inconspicuous size of the tentacles and pockets in the siphons.

Distribution.—Hauraki Gulf (New Zealand); all around Australia from Geraldton in the west, by way of south and east coasts to Thursday I. in the north-east.

(3) Microcosmus solanoides Herdman

Figs. 145-148

1899 *Cynthia solanoides* Herdman, p. 29, pl. Cyn. VIII.

External characters, test, and mantle.—See Herdman 1899. Lining the siphons there are, in the more external part, small, conical denticles, not curved and much smaller than those of *M. claudicans* (Fig. 145). I could distinguish no tentacles on the siphon lining. Further toward the base of the siphon there are 3 deep pockets in the mantle occupied by evagination of the siphon lining (Fig. 146).

Branchial sac.—With 8 folds on each side, 1 or 2 longitudinal bars between folds, and about 8 on the folds.

Dorsal lamina.—Short, narrow, and smooth.

Dorsal tubercle (Fig. 147).—The spongy appearance recorded by Herdman is due to the slightly convoluted nature of the very much coiled double spiral slit forming a double-coned tubercle.

Tentacles.—Large and much branched—6 large and 6 smaller alternating.

Alimentary canal (Fig. 148).—Forming 2 open loops. Oesophagus short. Stomach not differentiated. The liver is a large, arborescent organ of fan-shaped lamellae, not as compact as in *M. claudicans,* and situated at the angle of the anterior horizontal portion and the ascending limb of the first loop. The rectum is enlarged and parallel to the anterior part of the intestine. The anus has a smooth border as far as could be ascertained, but this portion of the specimen had been mutilated.

Gonads (Fig. 148).—Four large radiating gonads on the right. On the left are 3 "comma"-shaped organs. The most anterior of these is in the upper part of the alimentary loop, crossing the intestine. The second is about one-half the length of the anterior and posterior gonads and completely enclosed in the first loop. The most posterior gonad is in the second loop, parallel with the rectal portion of the intestine, but ventrally encroaching on the gut. Between the pole of the second loop and the liver are 2 block-shaped endocarps.

Relations.—This species is in some respects similar to *M. claudicans* but differs in the orientation and course of the gut, in the gonads, in the siphonal lining, in the dorsal tubercle, and in the branchial sac.

Distribution.—Only Herdman's type specimen from Port Jackson was available. Further description is given below, in addition to that of Herdman.

(4) Microcosmus nicholLsi, sp. nov.

Figs. 149-153

External characters.—Oblong, the breadth exceeding the height; 4 cm. long, 6 cm. broad. The branchial aperture is on the dorsal aspect of the posterior end; hence the apertures are spaced widely apart, on distinct and divergent siphons.

Test.—Leathery, thick, without any foreign bodies, and very wrinkled. The siphon lining contains conical spines, of varying sizes, slightly curved, the larger ones being twice the size of the smaller but much less numerous (Fig. 149). At the base of the siphon, just above the tentacle ring, is a series of about 8 pockets caused by evagination into the mantle, and above these the lining forms a continuous diaphragm (Fig. 150).

Mantle.—Muscular (Fig. 151).

Branchial sac.—With 7 overlapping folds on each side. Two longitudinal bars lie between the dorsal lamina and first fold, 20 on each fold and 1 or 2 between succeeding folds. Ten to 12 stigmata occupy each mesh, and are crossed by a horizontal membrane.

Dorsal lamina.—Smooth.

Dorsal tubercle (Fig. 152).—Fairly large. In 1 specimen the 2 horns were turned spirally inwards; in another specimen they were not spiralled but merely turned in.

Tentacles.—Large, fleshy, much branched.

Alimentary canal (Fig. 153).—A narrow, double loop. Oesophagus short, stomach not differentiated, liver compact. Rectum not expanded and anal border smooth.

Gonads.—Contained in a series of block-shaped endocarps; there are 5 on the left, extending along the dorsal wall of the alimentary canal (Fig. 153). On the right there are 4 postero-ventrally, and only in 1 of these has the gonad been developed.

Relations. — Closely related to *M. madagascariensis* but differing mainly in the branchial sac.

Distribution.—Flinders, Vic. (2 specimens).

(5) Microcosmus stolonifera, sp. nov.

Figs. 154-156

External characters.—Small, $\frac{3}{4}$-$1\frac{1}{2}$ in. long and $\frac{3}{4}$ in. wide; smaller specimens are more or less spherical, with protuberant, short siphons, both anterior, fairly close together and surrounded by a slight elevation of the test. Posteriorly the test is irregular and may be produced into short root-like processes, fixed to rocks etc. Around each aperture on the siphons are 4 short fingerlike projections of the test.

Test.—Thin, leathery, thickly encrusted with sand; purple.

Mantle. — Moderately muscular. Siphons lined with well-spaced, sharply pointed spines of a typical flattened shape distally, and with broad bases (Fig. 154).

Branchial tentacles.—Compound and bushy; 18 of alternating sizes, larger and smaller, with rudimentary ones interspersed.

Dorsal tubercle.—Fleshy; a U-shaped slit with inrolled horns, each on a mound of tissue (Fig. 155).

Dorsal lamina.—Broad, smooth, long.

Branchial sac.—Seven folds on each side of the body. Longitudinal bars: DL 0 (18) 1 (17) 0 (22) 0 (23) 1 (23) 1 (20) 1 (13) 0 E in the larger specimens; 9 stigmata in each mesh between the folds. Parastigmatic vessels usually present.

Alimentary canal (Fig. 156).—Forming a double narrow loop around the ventral margin of the body. The first loop encloses a row of endocarps,

the second the large, circular gonad. There is no enlargement of the stomach but there is a large lamellated liver in that region. Anal border 2-lipped.

Gonads (Fig. 156).—A large, spherical organ on each side of the body. The ovary overlies the central testes either partly or completely.

Relations.—Externally, larger specimens of this species appear to be similar to smaller specimens of *Pyura stolonifera*. The spines in the siphon are, however, distinctive.

Distribution.—Tiny I., east coast of Tasmania.

(6) Microcosmus helleri Herdman

Fig. 157

1880-1 *M. helleri* Herdman, p. 54.
1882 *M. helleri* Herdman, p. 131, pl. XIV, figs. 1-4.
1895 *M. helleri* Sluiter, p. 184.
1918 *M. goanus* Michaelsen, p. 12, figs. 1, 2.
1919 *M. helleri* Hartmeyer, p. 19, pl. 1, figs. 6-9.
1928 *M. helleri* Michaelsen and Hartmeyer, p. 397.

Further accounts of certain organs in this species are felt to be necessary in order to distinguish more certainly between this and other common forms of *Microcosmus*.

The siphon lining is evaginated downwards and outwards to form 3 pockets, as in *M. solanoides*, but there is also an internal invagination to form the 3 cones occluding the apertures, which have been mentioned by previous authors. There are no spines in the siphon.

Gonads (Fig. 157).—These form another feature that easily distinguishes the species from *M. claudicans* in that the most anterior gonad is enclosed in the only open portion of the alimentary canal, and the 2 succeeding gonads (the middle one being of double size) are placed end to end to form a continuous line with the most anterior gonad, the line crossing over the gut and following its course. On the right the gonads usually form a continuous mass.

Distribution.—Amboina, and north Australia from Shark Bay by way of Torres Strait to Great Barrier Reef. Also Trigg's I., W.A.

Family **MOLGULIDAE**

1. Genus MOLGULA Forbes and Hanley

Key to Species of the Genus Molgula

1. Testicular ducts open separately on the mesial surface of the ovary
M. medusa, sp. nov.*
Testicular ducts do not open on the mesial surface of the ovary 2
2. Folds represented by an approximation of 2 or 3 longitudinal bars 3
True folds present 8
3. Always with a stalk longer than the rest of the body 4
With or without a stalk (where present, shorter than the body) 5

4. Alimentary canal confined to the posterior part of the body
M. flagrifera Sluit. (Sluit. 1904)
Alimentary canal not confined to the posterior part of the body
M. longipedata Sluit. (Sluit. 1904)
5. Gonads round, oval or elongate 6
Gonads S-shaped . . . . . *M. reducta* Hart. (Mich. & Hart. 1928)
6. Dorsal tubercle a simple tube . . . . . *M. pyriformis* Herd. (Van Name 1945)
Dorsal tubercle with inrolled horns or slit opening 7
7. With hairs on the test . . . . . *M. calvata* Sluit. (Sluit. 1904)
Without hairs on the test . . . . . *M. inversa* Sluit. (Sluit. 1900)
8. Longitudinal bars in the branchial sac branch and ramify 9
Longitudinal bars run straight 10
9. Thick test . . . . . *M. gigantea* Herd. (Herd. 1882)
Thin test . . . . . *M. gregaria* Herd. (Herd. 1882)
10. Two or 3 bars on each fold 11
More than 4 bars on each fold 15
11. With infundibulae . . . . . *M. horrida* Herd. (Herd. 1882)
Without infundibulae 12
12. With lobed testes fringing the ovary 13
With compact, unlobed testes at distal end of ovary only 14
13. Test covered with hollow, wart-like projections
M. nodosa Hart.* (Mich. & Hart. 1928)
Without projections on the test . . . . . *M. minuta*, sp. nov.*
14. Mantle protrudes into hollow extensions of test around the apertures
M. janis, sp. nov.*
No hollow extensions of test around apertures . . *M. taprobane* Herd. (Herd. 1906)
15. With bars between the branchial folds 16
Without bars between the branchial folds 17
16. Twelve to 14 bars on each branchial fold . . . . *M. japonica* Hart. (Hart. 1906)
Less than 12 bars on each branchial fold . . *M. sabulosa* Q. & G.* (Van Name 1945)
17. Stigmata not much coiled and without infundibulae 18
Stigmata much coiled and with infundibulae 20
18. Tentacular projections of siphonal lining . . . . . *M. batemani*, sp. nov.*
No tentacular projections of siphonal lining 19
19. Conical siphons . . . . . *M. hozawai* Oka (Oka 1935)
Long, recurved siphons . . . . . *M. recumbens* Herd. (Herd. 1899)
20. Infundibulae between folds . . . . . *M. crinita* Sluit. (Sluit. 1904)
Infundibulae opposite folds 21
21. Alimentary canal ventral only . . . . . *M. sordida* Sluit. (Sluit. 1904)
Alimentary canal extends dorsally 22
22. Gonads enclosed in the first alimentary loop . . . *M. vitrea* Sluit. (Sluit. 1904)
Gonads not enclosed in the first alimentary loop 23
23. With siphons . . . . . *M. ridgewayi* Herd. (Mich. 1923)
Without siphons . . . . . *M. mollis* Herd.* (Herd. 1899)

(1) Molgula nodosa Hartmeyer

1922 *Molgula nodosa* Hartmeyer, p. 304, fig. 2.
1928 *Molgula nodosa* Hartmeyer and Michaelsen, p. 445, figs. 55-58.

External characters.—Irregular shape; fixed to sticks. Test covered with hollow, wart-like nodules. Branchial aperture anterior, atrial one-third of body-length along the dorsal surface; both apertures sessile, in a "nodule-free" area of the test.

Test.—Thin, brittle, encrusted with a thin layer of sand.

Mantle.—Thin, delicate, and protruding out into the hollow nodules in the test.

Branchial tentacles.—Eight large, compound, bushy tentacles and 8 smaller intermediate ones.

Dorsal tubercle.—Round, with its U-shaped slit directed to the right, and inrolled horns.

Fig. 158.—*Molgula janis.* Alimentary canal and gonads on the left side of the body. (× 1). Fig. 159.—*M. minuta.* Alimentary canal and gonads on the left side of the body. (× 4). Fig. 160.—*M. minuta.* Gonad and kidney from the right side of the body. (× 4). Fig. 161.—*M. medusa.* Gonad from the right side of the body showing central ovary, fringing testicular lobes, and testicular ducts rising from the surface of the ovary. (× 7.5). Fig. 162.—*M. mollis.* Siphonal spicules. (× 240). Figs. 163, 164.—*M. mollis.* Dorsal tubercle and neural gland and ganglion from two individuals. (× 7.5). Fig. 165.—*M. mollis.* Inner body wall of left and right sides showing kidney, gonad on the right, and alimentary canal and gonad on the left. (× ½). Fig. 166.—*M. sabulosa.* External appearance (*sabulosa* form). (× ¼). Fig. 167.—*M. sabulosa.* Dorsal tubercle. (× 7.5). Fig. 168.—*M. sabulosa.* Alimentary canal and gonads on the left side of the body. (× ½).

Dorsal lamina.—Plain and smooth.

Branchial sac.—Seven folds on each side of the body; no longitudinal bars between the folds, and about 4 on each fold; longitudinal bars strongly curved; stigmata not coiled, not forming infundibulae, but merely irregularly interrupted and slightly curved.

Alimentary canal.—Oesophagus opening two-thirds of the way down the length of the dorsal lamina (see Michaelsen and Hartmeyer 1928).

Gonads.—Elongate ovaries; testes branching off the distal end, but often more dense, and closer to the ovary than described by Michaelsen and Hartmeyer 1928.

Distribution.—Rare. Fremantle, Bunbury, W.A.

(2) Molgula janis, sp. nov.

Fig. 158

External characters.—Small, rounded specimens $\frac{1}{2}$-1 in. in diameter. Branchial aperture terminal, atrial one-third of body length along dorsal surface; both apertures protrude slightly and are surrounded by small, irregular, flap-like hollow extensions of the test, of which there are 4 around the atrial aperture and 6 around the branchial aperture.

Test.—Very thin, brittle, and with a thin layer of encrusting sand.

Mantle.—Extending out into the hollow extensions of test around the apertures. Musculature delicate.

Branchial tentacles.—Compound and bushy, 15-20, of irregular size.

Dorsal tubercle.—A W-shaped slit turned to the right, with inrolled horns; situated to the right and anterior to the dorsal ganglion.

Dorsal lamina.—A plain, smooth membrane.

Branchial sac.—Seven folds on each side, well spaced. No longitudinal vessels between the folds; 3 broad, flat vessels on the ventral side only of the folds. Stigmata numerous, mostly longitudinal, but some irregular or slightly coiled.

Alimentary canal (Fig. 158).—The usual narrow loop around the ventral margin of the body, the top of the loop being open; liver in the region usually occupied by stomach.

Gonads.—Ovary elongate, and testes forming a complete ring with the end of the ovary (Fig. 158).

Relations.—Closely related to *M. taprobane* Herd. but distinguished especially by the hollow extensions of test about the apertures into which the mantle protrudes.

Distribution.—Walkerville, Vic.; Victor Harbour, S.A.

(3) Molgula minuta, sp. nov.

Figs. 159, 160

External characters.—A minute, spherical species, of maximum diameter about $\frac{1}{8}$ in.; thus of similar size to *Polyandrocarpa* spp. Specimens found crowded together, occasionally stalked posteriorly; apertures anterior, sessile.

Test.—Thin, brittle, sand-encrusted, delicate.

Branchial tentacles.—About 15, not bushy, but having minute secondary branches.

Dorsal tubercle.—A simple slit lip opening.

Dorsal lamina.—Plain, smooth.

Branchial sac.—With 7 folds on each side; 3-4 longitudinal bars on each fold, no bars between folds. Stigmata forming definite spirals but not infundibulae in the folds.

Alimentary canal (Fig. 159).—The usual double narrow loop; liver lobes elongate; oval gonad in the second loop.

Gonads.—The distinguishing feature for the species; an oval ovary lies on the left, in the curve of the gut, on the right, parallel to and alongside the oval kidney. Testes situated in body wall all around the ovary, and in a few scattered lobes on top of the ovary (Fig. 159). In larger specimens the lobes of the testes spread out radiating, finger-like branches, in long lobes over the body wall for some distance around the ovary (Fig. 160).

Distribution.—Trigg's I., W.A.

(4) Molgula batemani, sp. nov.

External characters.—Of oval shape, 1 in. long, ½ in. wide. Both apertures anterior, sessile, with a thickened ridge of test between the apertures (reminiscent of some specimens of *M. sabulosa*); around each aperture are small, solid elevations of the test—4 around the branchial aperture and 6 around the atrial aperture. Test thin, transparent, almost free of foreign growths or sand encrustations.

Mantle.—Thin, delicate. Just inside the siphon are tentacular-like projections of the lining membrane borne on small cones between each of the externally projecting lobes, and at the sides and anterior to each of these tentacular projections (which point backwards) are more delicate projections, rigid at the tip and directed outwards—1 posteriorly on either side of the backward projections, and 2 further forward; on either side of the latter occur still more delicate projections. These have not been observed in any other species of *Molgula.*

Branchial tentacles.—Twelve, fairly long, with smaller ones between; primary branches fairly long, well spaced; secondary branches small; tentacles therefore not very bushy.

Dorsal tubercle.—A wide, rounded, U-shaped slit with inrolled horns; opening directed anteriorly; tubercle situated anterior to and to the left of the neural gland, and directly anterior to the ganglion.

Dorsal lamina.—Smooth, broad, and passing to left of the oesophageal opening.

Branchial sac.—Seven folds on each side of the body. No bars between the folds. Longitudinal bars on the ventral side only of folds: DL 0 (5) 0 (8) 0 (8) 0 (8) 0 (9) 0 (9) 0 (8) 0 E. Spirals not well marked.

Alimentary canal.—Of the usual form found in other species of this genus.

Gonads.—A shorter, thicker, more rounded ovary than is found in *Molgula janis*, sp. nov., and rather similar to the condition found in *M. sabulosa* Q. & G.

Relations.—This species is very closely allied to *M. sabulosa* Q. & G.; it differs in the branchial sac and the tentacular processes inside the siphon.

Distribution.—Fremantle, W.A.

(5) Molgula medusa, sp. nov.

Fig. 161

External characters.—Length $1\frac{1}{2}$ in., $\frac{3}{4}$ in. broad. Both apertures anterior, sessile, surrounded by very small and pointed lips.

Test.—Thin, coated with mud.

Mantle.—Delicate, with sparse musculature.

Branchial tentacles.—Ten; irregular sizes, the largest being found dorsally; secondary branches far apart but both primary and secondary branches quite long.

Dorsal tubercle.—Round, with a wide open U-shaped slit, turned to the right.

Dorsal lamina.—Plain, smooth, broad.

Branchial sac.—With 7 folds on each side of the body. Each fold has 2 broad, longitudinal bars only, and there are no bars between folds. The stigmata are not very much coiled on or between folds.

Alimentary canal.—Placed around the ventral margin of the body, enclosing the gonad, as is usual. Anal opening plain.

Gonads (Fig. 161).—These supply the distinguishing feature of this species. There is a long, rounded, tubular ovary with a central duct, opening near the anus; it is fringed by small, dendritic testicular lobes in the body wall around its distal end and extending over the sides of the ovary. Testicular ducts extend over the surface of the ovary into numerous and small upright tubes, sometimes branched, which occur thickly down the middle of the upper surface of the ovary and through which the testes discharge into the atrial cavity.

Relations.—The testicular ducts present here should prevent any confusion with other species. An Arctic species, *M. siphonalis* Sars. (see Van Name 1945, p. 379) has similar testicular ducts opening on the mesial surface of the ovary, though they are not as plentiful as in the present species; also, *M. siphonalis* has 6 or 7 longitudinal bars on each fold of the branchial sac.

Distribution.—Oyster Harbour, Albany, W.A.

(6) Molgula mollis Herdman
Figs. 162-165

1899 *M. mollis* Herdman, p. 54, pl. 1, figs. 1-4.
1899 *M. sydneyensis* Herdman, p. 55, pl. 1, figs. 5-9.

External characters.—Herdman describes his specimens as ovate-pyriform; the specimens seen by the writer are, however, rather circular and laterally compressed. They vary from 0.8 to 1.6 cm. in diameter. The body is not attached.

Test.—Thin, flexible, and covered with fine sand, which may make the test rather brittle and obscures the presence of fine projecting hairs. Embedded in the tissue of the test are a number of calcareous spicules, as in the siphon lining; also thickly ramifying vessels. The apertures on the anterior end are moderately far apart and only slightly projecting. In the upper part of the siphons are a number of simple tentacles, formed by projections of the mantle and the invagination from the test which lines the siphon. There are about 20 in a single circle and they project into the lumen, occluding the aperture. Also in the siphon lining are minute calcareous spicules (Fig. 162), rod- and star-shaped, embedded in the invagination from the test, not in the mantle.

Branchial sac.—With 7 folds on each side, 3 or 4 longitudinal bars on each fold, and no bars between folds. The infundibulae are arranged in a single row along each fold, the apex of the coil falling in the summit of each fold, the bases meeting in the spaces between folds. The spiral coils are large and between them run the transverse vessels. There is a large pre-pharyngeal region between tentacular ring and branchial basket.

Dorsal lamina.—A plain, fairly broad membrane.

Dorsal tubercle.—Of average size, simply U-shaped, or elliptical longitudinally. The neural ganglion lies dorsally slightly posterior and to the left, and the neural gland, although not as large as figured by Herdman, lies posteriorly and to the right (Figs. 163, 164).

Tentacles.—Sixteen, large and small alternating, much branched.

Alimentary canal (Fig. 165).—A single closed loop. Oesophagus short; much branched liver in the region of the stomach, which is otherwise not differentiated. The anal border is not lobed but its inner surface is grooved internally and is curved slightly back when contracted.

Gonads (Fig. 165).—On either side of the body, large and egg-shaped, with openings directed dorsally to the atrial opening. On the left the gonad lies in the curve of the alimentary canal.

Distribution.—Port Jackson (Herdman 1899), Twofold Bay (12 fathoms), N.S.W.

(7) Molgula sabulosa (Quoy and Gaimard)
Figs. 166-168

1834 *Ascidia sabulosa* Quoy and Gaimard, p. 613, pl. 91, figs. 19-22.
1840 *Cynthia sabulosa* Gervais, Dict. Sci. Nat. Suppl., vol. 1, p. 405.

1840 *Ascidia sabulosa* Dujardin, Lamarck Hist. An. s. vert, ed. 2, vol. 3, p. 536.
1859 *Caesira parasitica* and *C. ficus* Macdonald, pp. 367-370, pl. 64, fig. I, 1-6, fig. II, 1-6.
1881 *Molgula forbesi* Herdman, p. 236.
1881 *Molgula pedunculata* Herdman, pl. g, figs. 5-7.
1881 *Molgula pedunculata* Herdman, p. 234.
1882 *Molgula pedunculata* Herdman, p. 74, pl. 5, figs. 1-3.
1882 *Molgula forbesi* Herdman, p. 78, pl. 5, figs. 8-11.
1885 *Molgula forbesi* and *M. martensi* Traustedt, p. 19, pl. I, figs. 6, 7; pl. II, fig. 16.
1885 *M. forbesi* Sluiter, p. 180, pl. I, fig. 5; pl. 3, figs. 11-14.
1889 *M. forbesii* Whitelegge, p. 294.
1890 *M. forbesi* Sluiter, p. 330.
1891 *M. forbesi* + *M. martensii* + *Caesira parasitica* + *C. ficus* Herdman, pp. 568, 569.
1898*a* *Astropera sabulosa* Pizon, p. 273.
1898*b* *A. sabulosa, A. villosa* (err. pro *sabulosa*) Pizon, p. 343, pl. 13, figs. 6, 7; pl. 14, figs. 7, 8; pl. 15, fig. 7.
1898 *Ascopera nana* (nom. nud.) Herdman, p. 444.
1899 *Molgula forbesi* + ? *Ascopera nana* + *Caesira* (? *Molgula*) *parasitica* + *C.* (? *M.*) *ficus* + *Ascidia* (? *M.*) *sabulosa* Herdman, pp. 56, 108, pl. Cyn. 4, fig. 1; pp. 57, 108, pl. mol. 1, figs. 10-14.
1905 *Molgula maxima* Sluiter, p. 472.
1906 *Molgula maxima* Sluiter, p. 47; pl. 3, figs. 44, 45; pl. 5, fig. 59.
1906 *Molgula pedunculata* Sluiter, p. 48.
1908 *Molgula goddeffroyi* Michaelsen, p. 142, pl. 1, figs. 7-10; pl. 2, fig. 13.
1909 *M. mortoni* Kesteven, p. 289; pl. 25, figs. 4, 5; pl. 26, fig. 8; pl. 27, figs. 11, 12.
1909 *Caesira forbesi* + *C. godeffroyi* + *C. martensi* + *C. ficus* + *C. parasitica* + *Astropera sabulosa* + ? *Ascopera nana* + *Caesira mortoni* Hartmeyer, pp. 1323, 1324, 1325, 1328, 1483.
1909-11 *Caesira hodgsoni* Hartmeyer, p. 1739.
1909-11 *Caesira concomitans* Hartmeyer, p. 1739.
1909-11 *Caesira pedunculata* Hartmeyer, p. 1739.
1910 *Molgula concomitans* Herdman, p. 15; pl. 5, figs. 1 (pent), 2-7.
1910 *Molgula hodgsoni* Herdman, p. 11; pl. 3, figs. 7-13.
1911 *Caesira maxima* Hartmeyer, p. 417; pl. 45, fig. 2; pl. 48, figs. 1-4.
1912 *Caesira forbesi* Michaelsen, p. 170.
1914 *Molgula forbesi* + *Ctenicella martensii* + *C. ficus* + *C. parasitica* + *C. sabulosa* + *C. mortoni* + *C. godeffroyi* Hartmeyer, pp. 7, 13-18.
?1915 *Ctenicella nana* Michaelsen, vol. 1, p. 370.
1928 *Molgula sabulosa* Michaelsen and Hartmeyer, p. 449.
1938 *Molgula pedunculata* Arnbäck, p. 11.
1938 ? *Molgula angulata* Arnbäck, p. 9, fig. 3; pl. 1, figs. 9, 10.
1945 *Molgula pedunculata* Van Name, p. 410, fig. 300.

External characters (Fig. 166).—In external appearance lies the only distinction between the "*sabulosa*" form and the "*pedunculata*" form. However, there are intermediate stages between the 2 and the appearance varies with the state of contraction of the siphons, and with size of the animal (this cannot be stated with certainty as an age difference); also with the amount of sand covering the test (i.e. the type of environment in which the animal is growing).

Two specimens examined are identical with the type of *Ascopera nana* Herdman from the Australian Museum, being 2 cm. broad and 3.5 cm. in height, and posteriorly produced into a short stalk; the apertures are slightly ventral and dorsal respectively, and the test is produced anteriorly between them; the apertures are placed on short, wart-like siphons, the branchial aperture guarded by 6 lobes, the atrial by 4. On these lobes in tufts are the "tag-like" processes mentioned previously by Herdman (1910, p. 11) and other authors. More posteriorly these processes are more sparsely arranged and shorter. There is very little sand on the test.

There were also examined 2 specimens identical with the *M. mortoni* Kesteven type. They are 3 cm. broad, 3 cm. high; not produced posteriorly into a stalk; having the anterior projection of the test much reduced, leaving the branchial and atrial apertures more or less anterior; and having the processes of the test, especially those about the apertures, reduced in length and much obscured by sand.

The bulk of the specimens examined were larger, of the "*pedunculata*" or "*maxima*" type, 6-7 cm. broad and high. In these, anterior projection of the test has actually disappeared completely or is obscured by contraction of the siphons; hence branchial and atrial siphons appear close together and more or less in a distinct area surrounded by a slight invagination of the test (see *Pyura stolonifera* Heller). There are still 4 lobes about the atrial aperture and 6 protecting the branchial aperture, although the processes on the lobes around the mouth are much reduced and obscured and may be replaced by more sturdy and conical papillae. Processes all over the body are obscured by a thick layer of sand.

Apart from a slight difference in the development of the gonads, these external differences are the only points of distinction to be found after a very detailed examination of numbers of specimens. Nor is there any difference in geographical distribution. Possibly the larger forms are more successful on a sandy bottom; smaller ones prefer mud and maintain their delicate tentacular processes. Specimens of *M. mortoni* Kesteven type are definitely intermediate both in form and size, rather supporting the explanation of age differences.

In the branchial siphon the linings are invaginated to form a circular diaphragm above the tentacular ring, and in the atrial siphon the opening is reduced by this diaphragm to a transverse slit. Embedded in the lining are minute rod-shaped and globular calcareous spicules.

Mantle.—Fairly muscular; the internal siphons are anterior, fairly closely approximated basally, divergent, and of moderate length.

Branchial sac.—With 7 folds on each side, 17 bars on each fold, 2-4 between folds, 2-4 between the dorsal lamina and the first fold. There are no spirals on the folds but several are irregularly placed between folds. The longitudinal bars between the folds have a variable course and may

die out or be deflected on to the folds as they proceed posteriorly. There are never as many as 6-8 bars between the folds (Sluiter 1905, Hartmeyer 1910).

Dorsal lamina.—A short, plain membrane.

Dorsal tubercle (Fig. 167).—This lies in a fairly large peripharyngeal region (although not as extensive as that in *M. mollis*) and is invariable in its form—a spherical or elliptical cushion with an S-shaped slit, the horns being slightly spiral.

Tentacles.—These number 32, of varying sizes, large and small alternating.

Alimentary canal (Fig. 168).—Forming a double loop, the first loop narrow and closed, the second wide and open and accommodating the gonad on the left-hand side of the body; oesophagus moderately long; stomach surrounded by a compact and dense liver. The intestine then turns almost at a right angle and runs anteriorly and then doubles back, running parallel to the ascending portion. The anal border is smooth and slightly rolled back.

Gonads (Fig. 168).—One on either side of the body, placed, similarly to those of *M. mollis*, on the left in the second loop of the gut. The ovary is more or less triangular, with the testes, as in *M. mollis*, arranged more or less in a circle at its base and encroaching mesially over it. The ducts run down the centre of the ovaries. Arnbäck (1938), for *M. angulata*, has figured gonads with central ovary and marginal testes; this, together with the difference in course of the alimentary canal, would serve to distinguish her specimen and *M. sabulosa*. The renal organ is present in the usual position on the right-hand side.

Distribution.—Van Name 1945, p. 411 gives the following distribution —"circumpolar Antarctic, and to some extent, subantarctic form. Herdman's type of *pedunculata* was from South of Kerguelen Island in 150 fths. Sluiter's *M. maxima* was obtained near Booth Wandel and Antwerp Islands, and *M. angulata* Arnbäck at Paulet I., in the Western Antarctic region."

Further distribution—Moreton Bay, Bowen, Queensland; Port Jackson, N.S.W.; South Australia (Quoy and Gaimard 1834); Tasmania; Albany, Cockburn Sound, Shark Bay, W.A.; and Dampier Arch. (Traustedt 1885); also Malay Arch. (Sluiter 1885).

Order ENTEROGONA

Sub-order PHLEBOBRANCHIATA Lahille

Colonial or solitary; body seldom divided into thorax and abdomen. Sac usually with longitudinal bars but not folds. Gonads in loop of gut behind or alongside sac.

Family ASCIDIIDAE Huntsman

Colonial or solitary, gut to the left of sac. Stigmata straight, no languets.

(*a*) Subfamily Ascidiinae Herdman. Solitary.

(*b*) Subfamily Perophorinae Huus. Colonial.

Family CORELLIDAE Lahille

Solitary, without papillae, gut on right of sac. Dorsal lamina with languets.

Family CIONIDAE Lahille

Colonial or solitary; stomach behind sac; body divided into thorax and abdomen.

Family **ASCIDIIDAE**
Subfamily **ASCIDIINAE**
Genus ASCIDIA Linnaeus

KEY TO SPECIES OF THE GENUS ASCIDIA

1. Neural gland with openings to peribranchial cavity 33
   Neural gland without openings to peribranchial cavity 2
2. No papillae in branchial sac . . . . . *A. aspersa* Müller* (Brewin 1946)
   With papillae in branchial sac 3
3. With single loop in alimentary canal 32
   With double loop in alimentary canal 4
4. Prebranchial zone with papillae 5
   Prebranchial zone without papillae 9
5. Dorsal lamina smooth, test haired . . . . . *A. capillata* Sluit. (Sluit. 1887)
   Dorsal lamina with languets, teeth, or smooth. Test without hairs 6
6. Six stigmata in each mesh . . . . . *A. melanostoma* Sluit.* (Sluit. 1886)
   Two to 4 stigmata in each mesh 7
7. Small oval stigmata . . . . . *A. kuneides* Sluit. (Sluit. 1887)
   Long rectangular stigmata 8
8. Rectangular stomach . . . . . *A. austera* Sluit.* (Mich. & Hart. 1928)
   Spindle or spherical stomach . . . . . *A. gemmata* Sluit.* (Mich. & Hart. 1928)
9. With side buds on papillae . . . . . *A. munda* Sluit. (Mich. & Hart. 1928)
   Without side buds on papillae 10
10. Small teeth on surface of knobs on test . . . . . *A. armata* Hart. (Hart. 1906)
    No small teeth on surface of knobs on test 11
11. Two sizes of mesh in branchial sac . . . . . *A. limosa* Sluit. (Sluit. 1887)
    One size of mesh in branchial sac 12
12. Two to 5 stigmata per mesh 13
    More than 5 stigmata per mesh 21
13. With intermediate papillae in branchial sac 14
    Without intermediate papillae in branchial sac 15
14. Body small . . . . . *A. cylindracea* Herd. (Hart. 1926)
    Body large . . . . . *A. longistriata* Hart. (Hart. 1906)
15. Expansion of blood vessels along internal longitudinal bars
    A. nodosa Sluit. (Sluit. 1887)
    No expansion of blood vessels along internal longitudinal bars 16
16. Without outer siphons 17
    With outer siphons 20

17. Longitudinal meshes in branchial sac 18
Square meshes in branchial sac 19
18. Dorsal lamina strongly ribbed .. .. *A. dubia* Hart. (Mich. & Hart. 1928)
Dorsal lamina weakly ribbed .. .. *A. diplozoon* Sluit. (Sluit. 1887)
19. Branchial sac with conical papillae .. .. *A. archaia* Sluit. (Sluit. 1890)
Branchial sac with long, tapering papillae .. .. *A. falcigera* Herd. (Herd. 1882)
20. Atrial siphons longer than branchial *A. latesiphonica* Hart.* (Mich. & Hart. 1928)
Atrial siphons never longer than branchial
A. sydneyensis Stimps.* (Van Name 1945)
21. Eight to 12 stigmata .. .. *A. placenta* Herd. (Herd. 1882)
Four to 8 stigmata 22
22. With intermediate papillae in branchial sac 23
Without intermediate papillae in branchial sac 28
23. Branchial siphon 2 or 3 times the length of the atrial siphon
A. malaca Traust. (Mich. & Hart. 1928)
Branchial siphon less than twice the length of the atrial siphon 24
24. With 10 branchial and atrial lobes .. .. *A. decemplex* Sluit. (Sluit. 1890)
With 6-8 lobes on each aperture 25
25. With not more than 20 branchial tentacles 27
With 60-70 branchial tentacles 26
26. Atrial aperture 1/3 of body length from the branchial aperture
A. meridionalis Herd. (Van Name 1945)
Atrial aperture 1/2-2/3 of body length from the branchial aperture
A. thompsoni, sp. nov.*
27. Both intestinal loops open .. .. *A. rhabdophora* Sluit. (Mich. & Hart. 1928)
First intestinal loop closed .. .. *A. challengeri* Herd. (Van Name 1945)
28. Dorsal tubercle with several openings 29
Dorsal tubercle with one simple opening 30
29. With siphons .. .. *A. liberata* Sluit. (Sluit. 1887)
Without siphons .. .. *A. translucida* Herd. (Van Name 1945)
30. Without outer siphons .. .. *A. zara* Oka (Oka 1935)
With outer siphons 31
31. Siphon wart-like .. .. *A. glabra* Hart. (Mich. & Hart. 1928)
Siphons short-cylindrical .. .. *A. samea* Oka (Oka 1935)
32. Without folds in branchial sac .. .. *A. lagena* Mich. (Mich. 1922)
With large fold in branchial sac .. .. *A. aclara*, sp. nov.*
33. With intermediate papillae in branchial sac *A. obesa* (Herd.)* (Mich. & Hart. 1928)
Without intermediate papillae in branchial sac 34
34. Extra tubercular openings in a regular long line .. *A. juliinea* Sluit.* (Hart. 1919)
Extra tubercular openings spread over wide area *A. nigra* (Sav.)* (Van Name 1945)

Species not included in key: *A. vasculosa*—square externally (Herdman 1882); *A. despecta*—3-5 stigmata; papillae on test (Herdman 1882).

(1) Ascidia obesa (Herdman)

1880-81 *Pachychlaena oblonga* + *P. obesa* Herdman, pp. 461, 462.
1882 *Pachychlaena oblonga* + *P. obesa* Herdman, p. 22, pl. 29, figs. 1-9; p. 223, pl. 28, figs. 1-5.
1885 *Phallusia oblonga* + *P. obesa* Traustedt, p. 16.
1891*a* *Pachychlaena oblonga* + *P. obesa* Herdman, p. 596.
1898 *Ascidia phallusioides* nom. nud. + *Pachychlaena oblonga* + *P. obesa* Herdman, p. 446.
1899 *Ascidia* s. *Phallusia phallusioides* + *Pachychlaena oblonga* + *P. obesa* Herdman, p. 12, pl. Asc. 2, p. 15.

1909 *Phallusia obesa* + *P. oblonga* + *Phallusiopsis phallusioides* Hartmeyer, pp. 1403, 1408.
1913*a* *Phallusia phallusioides* Julin and Robert, p. 636.
1913*b* *Phallusia* s. *Phallusiopsis phallusioides* Julin and Robert, p. 296.
1928 *Phallusia obesa* Michaelsen and Hartmeyer, p. 308.

External characters. — Body large, rounded posteriorly, yellowish brown and covered with black pigment spots; with rounded longitudinal furrows. Branchial aperture anterior, the siphon being curved to the right; atrial aperture sessile just behind it.

Fig. 169.—*Ascidia gemmata.* Body removed from the test, showing position of the alimentary canal. (× ½). Fig. 170.—*A. aclara.* Dorsal tubercle and line of attachment of the branchial sac. (× 7.5). Fig. 171.—*A. aclara.* External appearance. (× ¼). Fig. 172.—*A. aclara.* Alimentary canal. (× ¼). Fig. 173.—*A. sydneyensis.* Alimentary canal. (× ½). Fig. 174.—*A. thompsoni.* Branchial papillae. (× 7.5). Fig. 175.—*A. thompsoni.* Alimentary canal. (× ½).

Mantle.—With fine circular musculature, the muscles being scattered and strong.

Tentacles.—About 65 in number, the longer alternating with 2-5 shorter ones.

Dorsal tubercle.—A minute, U-shaped slit inclined slightly to the right, opening into the peribranchial cavity (see Herdman 1899, pl. As. II, fig. 7).

Dorsal lamina.—A double membrane for the anterior part of its length but becoming single posteriorly; thin, wide, flaccid, and ribbed, the free edge with closely packed tentacular languets.

Branchial sac.—With large, wide, rectangular stigmata, 5 or 6 in each mesh; papillae sickle-shaped, with smaller intermediate ones.

Alimentary canal.—Occupying the posterior part of the body (see Michaelsen and Hartmeyer 1928 p. 309, fig. 19).

Gonads.—A large, circular ovary on the gut loop, with a thick duct leading from it; testes ramifying over the surface of the alimentary canal.

Distribution.—Between Shark Bay and Albany, W.A.; Bass Strait; Port Jackson, N.S.W.

(2) Ascidia juliinea (Sluiter)

1919 *Phallusia juliinea* Sluiter, p. 7, pl. 1, figs. 13-16.
1919 *Phallusia juliinea* Hartmeyer, p. 99, pl. 2, figs. 51-53.

External characters.—Similar in size to *A. obesa,* but more cylindrical and not so enlarged posteriorly. Colour whitish yellow. Slight longitudinal furrows present. Branchial siphon anterior, turned to the right. Atrial siphon just behind the branchial siphon but considerably shorter. No black pigment spots in the test.

Test.—Thick, white, gelatinous.

Mantle.—Rather more delicate and transparent than *A. obesa.*

Tentacles.—Not very long, about 100, with bases almost touching; smaller, finer ones alternate with those of larger size.

Dorsal tubercle.—Very small, U-shaped, slight; secondary openings lie along a duct between the dorsal tubercle and the neural ganglion, just anterior to the base of the atrial siphon, and one-third of the way down the body length.

Dorsal lamina.—A fairly broad lamina, double anteriorly, single posteriorly. The ribs are very wide, and end in thick languets.

Branchial sac.—With about 5 stigmata per mesh, minute plications, and closely grouped longitudinal bars; there are large, spatulate papillae but no intermediate papillae.

Alimentary canal.—Stomach much enlarged, with external furrows; oesophageal opening half-way down branchial sac; narrow intestinal loop extending anteriorly to the middle of the body; anal opening fringed with fairly long lobes.

Gonads.—Ovary long, compressed in the alimentary loop, not round as in *A. obesa;* testes extending over the alimentary canal.

Distribution. — Java; Cape Jaubert (north coast of Western Australia).

(3) Ascidia nigra (Savigny)

1816 *Phallusia nigra* Savigny, p. 163, pl. 2, fig. 2; pl. 9, fig. 1 (reprinted in Isis, 1820, p. 803, figs. on pl. 9 and 11).
1823 *Ascidia atra* Lesueur, p. 2, pl. 1, fig. 2.
1852-56 *Phallusia violacea* Gould, p. 495; atlas, p. 16, pl. 42, fig. 610.
1878 *Ascidia nigra* Heller, p. 92.
1880 *Ascidia nigra* Herdman, p. 466.
1882 *Ascidia nigra* Herdman, p. 210.
1882 *Phallusia atra* Traustedt, pp. 278, 286, pl. 4, fig. 6; pl. 5, fig. 17.
1884 *Ascidia nigra* Von Drasche, p. 383, pl. 8, figs. 5-7.

1897 *Ascidia atra* Metcalf, p. 143.
1898 *Ascidia atra* Sluiter, p. 7.
1900 *Ascidia atra* Metcalf, pp. 500, 502, figs. A-D.
1900 *Ascidia nigra* Verrill, p. 588.
1902 *Ascidia atra* Van Name, p. 398, pl. 63, figs. 138, 139.
1908 *Thallusia nigra* Hartmeyer, 1908, p. 111 (misprint).
1909 *Phallusiopsis nigra* Hartmeyer, pp. 1408, 1630, etc.
1912 *Phallusiopsis nigra* Hartmeyer, pp. 361, 363.
1914 *Tunica nigra* Hilton, p. 113.
1916 *Phallusia nigra* Hartmeyer, p. 408, figs. 5-9.
1916 *Ascidia atra* Hecht, pp. 429 etc.
1916 *Ascidia atra* Pratt, p. 667.
1918 *Ascidia atra* Hecht, pp. 229 etc.
1918 *Phallusia nigra* Michaelsen, p. 60. 1919, p. 113.
1921 *Phallusia nigra* Van Name, p. 379, figs. 55-58; 1924, p. 27.
1930 *Ascidia nigra* Van Name, p. 463, fig. 35, pl. 7, upper figure.
1935 *Phallusia nigra* Grave, pp. 215, etc., pl. 2, figs. 5-9.
1935 *Ascidia nigra* Pratt, p. 745.
1937 *Ascidia nigra* Plough and Jones, p. 101.
1945 *Ascidia nigra* Van Name, p. 184.

External characters.—Body furrowed longitudinally; black in a smaller specimen, violet-black in a larger specimen; wider in relation to length than previous species; branchial aperture terminal and turned to the right, atrial aperture just behind this; both apertures short.

Mantle.—Moderately muscular; colour greyish.

Tentacles.—About 50, fairly short, alternating with minute rudimentary ones.

Dorsal tubercle.—A simply U-shaped slit. In a clump behind the tubercle, in front of the ganglion, and as in *A. obesa,* there are secondary openings into the peribranchial cavity.

Dorsal lamina.—A broad, strongly ribbed membrane. The ribs end in fairly sturdy languets.

Branchial sac.—Five or 6 stigmata per mesh; longitudinal vessels serried; papillae long, pointed; intermediate papillae absent.

Alimentary canal.—The stomach is represented by a slight rectangular enlargement; the intestine is enlarged as in *A. obesa;* the anus is lobed as in *A. juliinea.*

Gonads.—Ovary oval, in loop of stomach; not as compressed as in *A. juliinea.* Testes ramifying over canal.

Distribution.—Red Sea; east coast North and South America; Gulf of Aden; Pittwater, N.S.W.

(4) Ascidia austera Sluiter

1904 *Ascidia austera* Sluiter, p. 39, pl. 6, figs. 6-8.
1909 *Phallusia austera* Hartmeyer, p. 1401.
1928 *Ascidia austera* Michaelsen and Hartmeyer, p. 297.

External characters.—Two specimens examined are 2 in. long, 1 in. broad. Their shape is irregular, their branchial apertures are terminal,

and atrial apertures one-third of the body length distant. In one specimen the apertures are almost sessile; in the other they are both long, the atrial siphon reaching as far anteriorly as the branchial; the former is 6-lobed, the latter 4-lobed, and both are marked with similar longitudinal furrows.

Test.—The smaller specimen has a thicker test, white and smooth externally; the test of the larger specimen is transparent greyish, the densest grey being around the siphons; it is smooth externally, firm, and fairly thick.

Mantle.—Not very muscular.

Tentacles.—Numbering about 50, simple, fairly long, but varying in size. Prebranchial area covered with minute papillae.

Dorsal tubercle.—A fairly elongate simple U, or with the right horn folding anteriorly over the left horn.

Dorsal lamina.—A broad membrane, strongly ribbed with minute, thin languets at the free edge of each rib.

Branchial sac.—Stigmata 36 per mesh; longitudinal vessels very numerous, about 45 on each side, borne on large papillae, curved over; intermediate papillae absent. (See Sluiter 1904, pl. VI, fig. 7.)

Alimentary canal.—A double narrow loop, occupying most of the area of the left body wall; with a slightly rectangular stomach enlargement.

Gonads.—Enclosed in the alimentary loop and spreading over the alimentary canal.

Distribution.—Australia: Moreton Bay, Thursday I., Queensland; Albany, W.A.; Malaya (Sluiter).

(5) Ascidia aspersa Müll.

1881 *A. aspersa* + *A. tunicata* Herdman, pp. 274-290.
1905 *A. aculeata* (part) + *A. canina* (non Müll.) + *A. normani* + do. (var. *resplendens*) + *A. affinis* + *A. pustlilosa* + *A. scabra* (var. *echinata*) Alder and Hancock, pp. 114, 122, 128, 132, 136, 138, pl.
1930 *A. aspersa* Lindsay and Thompson, p. 3.
1946 *A. aspersa* Brewin, p. 107.

External characters.—Body oval, 2.5-6 cm. long and 2-3.5 cm. wide, fixed posteriorly; branchial aperture terminal and sessile; atrial aperture on a short cylindrical siphon, half-way down the dorsal surface; branchial aperture surrounded by 8-10 lobes, each bearing a tongue-like projection of the test with pointed papillae and a thickened cuticular covering. The 6-lobed atrial aperture bears similar papillae. The right side of the test bears scattered, rounded prominences covered with pointed papillae.

Test.—Thin and flaccid, semi-transparent, but thicker on the right than on the left.

Mantle.—The musculature is weak. The mantle is produced into lobes around the mouth.

Branchial sac.—This extends posteriorly beyond the alimentary canal, and is minutely plicated. The internal longitudinal bars number about 36-45 on each side and are borne on the free end of the tall papillae along the transverse vessels. Thus no part of the branchial papillae projects freely into the pharyngeal cavity. The transverse vessels are all of one width. There are about 8 longitudinally directed stigmata in each mesh, but no intermediate papillae.

Dorsal lamina.—A plain, double membrane ribbed on both sides.

Dorsal tubercle.—A circular cushion with a simple slit, opening anteriorly and with the horns both turned in or to the left.

Branchial tentacles.—About 30 simple tentacles, large and small alternating. Their bases are broad and touching and the tentacles taper suddenly from the base, giving a triangular appearance.

Alimentary canal.—A double loop. The pole of the first loop is slightly more posterior than, or on the same level as, the anal opening. The first loop is closed, the second wide open. The oesophagus is long, the stomach spindle-shaped and not folded. The anal border is smooth.

Gonads.—Placed in the first loop of the alimentary canal. The duct runs anteriorly parallel to the rectum.

Distribution.—Europe—Mediterranean to Shetland Isles (Lindsay and Thompson); Otago Harbour (Brewin); Australia — D'Entrecasteaux Channel, Tas.; Oyster Harbour, Albany, W.A.; Port Noarlunga, S.A.

Brewin (1946, p. 108) suggests that this species may have been introduced to Otago Harbour by ships. If this is so then presumably it reached Tasmania by the same means. It seems unlikely, however, that specimens from both D'Entrecasteaux Channel and Otago came from such a source; more probably the distribution of the species is more cosmopolitan than has hitherto been recognized.

(6) Ascidia gemmata Sluiter

Fig. 169

1895 *Ascidia gemmata* Sluiter, p. 177, pl. 9, figs. 7-9.
1896 *Ascidia gemmana* (err.) Della Valle, p. 5.
1899 *Ascidia gemmata* Herdman, pp. 15, 111.
1904 *Ascidia gemmata* Sluiter, p. 29.
1909 *Phallusia gemmata* Hartmeyer, p. 1402.
1919 *Ascidia gemmata* Hartmeyer, p. 95, pl. 2, fig. 49, fig. 19.
1928 *Ascidia gemmata* Michaelsen and Hartmeyer, p. 292.

External characters.—Specimens small—4-6.5 cm. long and 2-2.5 cm. broad; body elongate; branchial aperture terminal, borne on a long, cylindrical siphon; atrial aperture in the posterior third of the body, on a short, cylindrical siphon directed posteriorly.

Test.—Thin, semi-transparent. On the left it is covered with sand and calcareous particles. On the right it is thicker, with a rough surface.

Mantle.—Very delicate; internal atrial siphon as long as the branchial, and directed posteriorly. It arises from half-way down the body. Branchial siphon turned ventrally and posteriorly. Minute papillae occur in the prebranchial area—these have not hitherto been recorded.

Branchial sac.—With about 4-6 stigmata per mesh; minutely plicated; papillae bear the longitudinal vessels about half-way along their length. These papillae are large, with a rounded, bent-over tip, but the side buds on the papillae were not very clear in specimens examined, possibly due to poor preservation.

Dorsal lamina.—Broad and strongly ribbed, bearing sturdy languets at the free ends of the ribs.

Dorsal tubercle.—Simple, with a rather elongate U-shaped slit, the opening being directed anteriorly, and the horns turned to the left.

Tentacles.—About 50, fairly long.

Alimentary canal (Fig. 169).—A double loop. The first loop is closed and the second widely open. The pole of the first loop extends anteriorly to the anus. The oesophagus is fairly long, the stomach being spindle-shaped or almost spherical, and bent acutely into the intestine. The spindle-shaped stomachs in some of these specimens are much longer than those figured by Michaelsen and Hartmeyer (1928, fig. 8, p. 294). The rectum runs transversely to the base of the atrial siphon.

Gonads.—Enclosed in the first alimentary loop.

Relations.—Despite irregularities such as absence of buds on the papillae and papillae in the prebranchial area, the alimentary canal and the position of the siphons are typical and specific.

Distribution.—Malaya (Sluiter); Celebes; Australia—Cape Jaubert, Shark Bay, Fremantle, Albany, W.A.; San Remo, Vic.; and Port Jackson, N.S.W.

(7) Ascidia aclara, sp. nov.

Figs. 170-172

External characters (Fig. 171).—The body is more or less regularly rectangular, the dimensions being 10 by 5 cm. The branchial aperture is terminal on a short cylindrical siphon. The atrial aperture is similar, and situated one-third of the body length down the dorsal surface. Both apertures are directed dorsally and without lobes. The test, including the siphons, is covered with sand and calcareous particles; the right side is fixed to a scallop shell. The sand and other particles are actually buried in the thin test, making it very brittle.

Mantle.—With weak musculature generally, localized in the circular siphon spincters and in transverse bands just below the atrial siphon. Internal siphons short and cylindrical.

Branchial sac.—Particularly characteristic, due to a large fold falling from the anterior to the dorsal tubercle, across it, and running the whole length of the sac (Fig. 170). There are about 84 longitudinal bars on either side of the sac, excluding the fold; they are borne out from the plane of the transverse vessels by the papillae, which are short but finger-like; no intermediate papillae occur. The transverse vessels are broad. There are minute plications in the sac, and 5 stigmata per mesh. The branchial sac extends posteriorly considerably beyond the alimentary canal.

Dorsal lamina.—Placed on the right of the base of the fold in the branchial sac. It is not very broad, and is smooth-edged and ribbed.

Dorsal tubercle (Fig. 170).—A rounded cushion with a complicated convoluted slit, covered by the branchial fold. Owing to the nature of the origin of the branchial sac in this region, the peritubercular area is transverse, bordered anteriorly, posteriorly, and on the left by the attachment of the branchial sac.

Branchial tentacles.—All of more or less the same size. They are longer than the siphon, crowded, and about 200 in number.

Alimentary canal (Fig. 172).—Forming a simple, open loop; oesophagus short, stomach oval and directed postero-dorsally; intestine short and broad, opening in a broad anus at the base of the atrial siphon. The alimentary tract is filled with sand.

Gonads.—No gonads are visible in this specimen.

Relations.—This species is distinguishable by the simple form of the alimentary canal and the brittle, thin test.

Distribution.—One specimen from Lakes Entrance, Vic.

(8) Ascidia sydneyensis Stimpson

Fig. 173

1855 *Ascidia sydneyensis* (? part) Stimpson, p. 387.
1878 *Ascidia canaliculata* Heller, p. 84, pl. 1, fig. 1.
1879 *A. urdis* (non Alder 1863) (part) Schmeltz, p. 89.
1880-81 *A. pyriformis* Herdman, pp. 468, 715.
1882 *A. pyriformis* Herdman, p. 219, pl. 34, figs. 1-6.
1885 *Ascidia canaliculata?* Sluiter, p. 126, pl. I, fig. 4, pl. 3, figs. 6-10.
1885 *Phallusia longitubis* Traustedt, pp. 15, 16.
1885 *Phallusia longitubis* Traustedt, p. 16.
1889 *Ascidia sydneiensis* + *A. pyriformis* Whitelegge, p. 295.
1891*a* *A. pyriformis* + *A. canaliculata* + *A. longitubis* + *A. sydneiensis* (sp. dub.) Herdman, pp. 593-5.
1894 *Phallusia longitubis* Traustedt and Weltner, p. 10.
1897 *Ascidia canaliculata* + *A. divisa* (nom. nov. pro *A. canaliculata?* Sluiter 1885) Sluiter, p. 45, pl. 5, figs. 15-18; p. 43.
1898 *A. longitubis* Sluiter, p. 8, pl. 1, figs. 1, 2.
1898 *A. incerta* (nom. nud.) Herdman, p. 446.
1899 *A. incerta* + *A. pyriformis* + *A. sydneiensis* Herdman, p. 11, pl. Asc. 1, figs. 5-8; pp. 15, 53, 111.

?1901 *A. longitudinalis* (nom. nud.? err. pro *longitubis*) Seeliger, p. 411.
1904 *A. divisa* Sluiter, p. 30, pl. 5, fig. 20.
1906 *A. divisa* Hartmeyer, p. 21.
1906 *A. obligira* (non Alder 1863) Rennie and Wisemen, p. 905, pl. 64, figs. 10, 11.
1909 *Phallusia canaliculata* + *P. divisa* + *P. incerta* + *P. longitubis* + *P. pyriformis* + *P. sydneiensis* (sp. dub.) Hartmeyer, pp. 1401-5.
non 1909 *Ciona intestinalis* var. *sydneiensis* Kesteven, p. 282.
1911 *Phallusia canaliculata* Hartmeyer, p. 576, pl. 57, figs. 13, 14.
1913 *Phallusia canaliculata* Hartmeyer, p. 135.
1915*b* *Phallusia sydneiensis* Hartmeyer, p. 313.
1918 *Ascidia canaliculata* Michaelsen, p. 59.
1919 *Ascidia sydneiensis* Hartmeyer, p. 98, pl. 2, fig. 50.
1921 *Phallusia sydneiensis* Van Name, p. 386, figs. 62-65.
1928 *Ascidia sydneiensis* Michaelsen and Hartmeyer, p. 285.
1930 *Ascidia sydneiensis* Van Name, p. 386, figs. 62-65.
1945 *Ascidia sydneiensis* Van Name, p. 189, fig. 101.

External characters.—Specimens vary in size from 18 to 20 cm. in length and 5-10 cm. in breadth. The branchial siphon is terminal, short, and cylindrical, with 8 lobes and corresponding furrows down the side of the siphon. The atrial siphon is similar, but 6-lobed, one-third to one-half of the body length down the dorsal surface; but in some individuals the atrial aperture is sessile, and in a few cases both siphons are very elongate.

Test.—Fairly thick, but occasionally thin, gelatinous and semi-transparent. In larger specimens there are the "tag-like excrescences" mentioned by Herdman, but in smaller individuals the test is merely roughened. Posteriorly the test is produced into longer root-like processes which help to fix the animal in the mud.

Mantle.—Musculature weak (see Van Name 1945). The internal siphons, especially the branchial, are much longer than appears externally.

Branchial sac.—The number of longitudinal bars varies with the size of the animal; large individuals from Tasmania have 100 bars on each side while the smallest individuals have only about 30. The longitudinal bars are slightly raised from the plane of the transverse vessels by the large papillae. There are no intermediate papillae. There are 4 stigmata in each mesh, and minute plications in the sac.

Dorsal lamina.—Smooth and ribbed.

Dorsal tubercle.—Specimens from Spring Bay show a gradual gradation, directly related to size, in the complication of the tubercular slit, which varies from a simple U-shape, with inrolled horns, to a much convoluted pattern. But in all cases the tubercle almost completely fills the peritubercular area. The gradation in the complication of tubercles in individuals from the one area does not support the hypothesis of Michaelsen and Hartmeyer (1928) of a relationship between the dorsal tubercle and the geographical area to which the specimens belong.

Tentacles.—These increase in number with the increase in number of branchial bars, and always exceed the number of bars on any one side of the body.

Alimentary canal (Fig. 173).—Particularly notable in these forms is the great mass of compacted mud in the intestine, increasing in quantity in older forms until the rest of the canal is obscured. The mud is first deposited in the descending limb of the first alimentary loop and this increases in size. The only other record of a similar occurrence is for *A. munda* (Michaelsen and Hartmeyer 1928, p. 296), though here the enlargement of the intestine is not as great. It has not been recorded before for *A. sydneyensis* Stimps., although all specimens, except a few from Balnarring Beach, contained mud in the intestine. Since the stomach in the latter forms is pyriform, sharply cut off from the oesophagus, while in mud-filled forms the stomach is more sharply cut off from the intestine it is possible that there is a specific difference between the two which examination of further specimens will uncover. The anal border is weakly lobed and is situated below the pole of the first intestinal loop.

Gonads.—Lying in the first loop, but obscured by the expansion due to gut contents.

Distribution.—West Indies, Hawaii, Malay Arch., Amboina, Japan, South Africa; Australia—Cape Jaubert, Shark Bay, Fremantle, Albany, W.A.; Victor Harbour and Port Noarlunga, S.A.; Spring Bay, Tas.; Balnarring Beach, Point Leo, Vic.; Port Jackson, N.S.W.

(9) Ascidia thompsoni, sp. nov.

Figs. 174, 175

External characters.—Appearance rather like *A. sydneyensis* Herdman; 6.5 cm. long and 4.5 cm. broad; laterally compressed; the short cylindrical branchial siphon is terminal and has 8 lobes and corresponding furrows down the cylinder. Situated from one-half to two-thirds of the way down the dorsal surface, the atrial siphon is a similar short cylinder, with 6 lobes.

Test.—Thin and semi-transparent, with a sparse sand encrustation all over, otherwise smooth.

Mantle.—Delicate.

Branchial sac.—Extending posteriorly to the alimentary canal, and minutely plicated. About 50 longitudinal bars occur on each side, being borne half-way along the papillae occurring at the corner of each mesh. These papillae are large and curved, with an enlarged free end, and arising from the longitudinal bars are more slender, but equally long, intermediate papillae (Fig. 174). There are 6-8 stigmata per mesh.

Dorsal lamina.—A broad and smooth double membrane, strongly ribbed on the left.

Dorsal tubercle.—A simple, U-shaped slit directed anteriorly.

Branchial tentacles.—Fairly closely packed, about 70 in number, with very little variation in size.

Alimentary canal (Fig. 175).—A double loop; both loops are open. The oesophagus is fairly long, and the stomach sharply cut off from, but not very much wider than, the oesophagus. It rapidly merges into the intestine, which runs anteriorly for about two-thirds of the body length, then forms a wide loop and follows an S-shaped course to the anal opening, which lies considerably posterior to the pole of the first loop. The anal border is weakly lobed. The stomach is covered with tubules.

Gonads.—Occupying the first loop of the gut.

Relations.—This species is in some ways similar to *A. decemplex* Sluiter but differs in the siphon lobes, in the course of the alimentary canal and of the longitudinal bars, and in the dorsal lamina.

Distribution.—Great Taylor Bay, Tas.—one specimen only.

Subfamily **PEROPHORINAE**

Genus PEROPHORA Wiegmann

KEY TO SPECIES OF THE GENUS PEROPHORA

1. Four rows of stigmata 2
   Five to 6 or more rows of stigmata 3
2. With internal longitudinal bars .. .. *P. viridis* Verrill (Van Name 1945)
   Without internal longitudinal bars .. .. .. *P. annectens* Ritter (Van Name 1945)
3. Testes fan-shaped .. .. *P. multistigmata*, sp. nov.*
   Testes oval 4
4. Test sandy .. .. *P. hutchisoni* Macdonald (Mich. & Hart. 1928)
   No sand on test .. .. *P. bermudensis* Berrill* (Van Name 1945)

(1) PEROPHORA MULTISTIGMATA, sp. nov.

Figs. 176, 177

External characters.—The small rectangular zooids are connected by a network of stalks on each of which is a sessile individual. The branchial siphon is terminal, wart-like, and cylindrical, the aperture being fringed by about 10 pointed lobes (Fig. 176). The atrial aperture is at the end of a rather longer and narrower cylindrical siphon, projecting from the antero-dorsal corner of the rectangular zooid. The aperture here, too, is fringed by about 10 pointed languets.

Test.—Thin, gelatinous, and transparent, without any foreign bodies attached.

Mantle.—Delicate, with strong muscles in the siphons. It is only very weakly attached to the test. It is transparent, and a ramifying network of blood vessels is clearly seen.

Branchial sac.—With 8 rows of long, oval stigmata. There are about 12 longitudinal bars and 16 stigmata in a row on either side. The

longitudinal bars are borne on papillae. There are, near the endostyle, 2 stigmata in each mesh, but near the dorsal lamina there is only 1.

Dorsal lamina.—A smooth membrane with 2 or 3 indentations along its course.

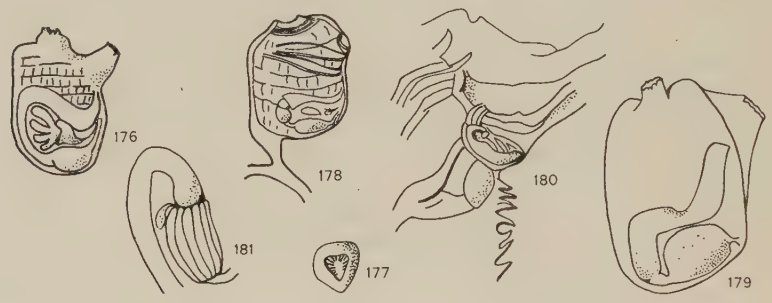


Fig. 176.—*Perophora multistigmata.* External appearance. (× 7.5). Fig. 177.—*P. multistigmata.* Dorsal tubercle. (× 15). Fig. 178.—*P. bermudensis.* External appearance. (× 7.5). Fig. 179.—*Ecteinascidia flora.* Body from the left side showing position of the alimentary canal. (× 7.5). Fig. 180.—*Rhodosoma turcicum.* Peritubercular area, showing neural gland and ganglion, dorsal tubercle, and anterior part of the dorsal lamina. (× 7.5). Fig. 181.—*R. turcicum.* Part of alimentary canal to show the stomach and pyloric caecum. (× 7.5).

Dorsal tubercle (Fig. 177).—A triangular cushion, with its apex directed posteriorly, and with a triangular hollow in the centre.

Branchial tentacles.—Simple; 30, fairly long and directed posteriorly, alternate with an equal number of shorter ones of half the length, directed anteriorly. The tentacles are crowded together and their bases touch. Attached to the tentacles are numerous protozoa of the "*Euplotes*" type, which appeared at first glance as enlargements of the tentacle.

Alimentary canal.—Forming a double loop, both loops being open. The oesophagus is long and narrow and the stomach is oval, lying transversely across the posterior part of the body; the intestine is fairly wide, following an S-shaped course across the body, to terminate in an anteriorly directed rectum. The pole of the first alimentary loop does not extend anteriorly beyond the anus.

Gonads.—Enclosed in the first alimentary loop. There are a fan-shaped testis of 4 or 5 lobes, and a compact ovary (as in *P. viridis* Verrill). Developing eggs and larvae occur in the right peribranchial cavity.

Relations.—Distinguished from other species by the large number of rows of stigmata in the branchial sac.

Distribution.—Dunwich, Queensland.

(2) Perophora bermudensis Berrill

Fig. 178

1932 *Perophora bermudensis* Berrill, pp. 78, 82, fig. 3*a*.
1935 *Perophora bermudensis* Berrill, pt. 4, p. 358, fig. 16*a*.
1935 *Perophora bermudensis* Arnbäck, pp. 4, 5, fig. 1.
1937 *Perophora bermudensis* Plough and Jones, p. 100.
1939 *Perophora bermudensis* Plough and Jones, p. 51, fig. 1*e*.
1945 *Perophora bermudensis* Van Name, p. 167, figs. 81A, 82E, 84.

External characters (Fig. 178).—Body transparent, almost square, attached to a ramifying hydrorhiza by a short stalk from the postero-ventral aspect. The zooids are less densely distributed than in the previously described species; and the stolon is less ramifying. The branchial aperture is terminal and sessile; the atrial aperture is on the anterior third of the dorsal surface and is also sessile. There are 7 conical lobes protecting each aperture.

Test.—Transparent, smooth.

Mantle.—Delicate and transparent. There are a few circular sphincter muscles around each siphon, and 46 oblique or transverse bands running across the dorsal surface behind the atrial siphon and converging on either side of the endostyle. These muscle bands are quite constant and characteristic, but have not been described before for this species. The mantle is closely adherent to the test.

Branchial sac.—With 5 rows, each of 16 long, oval stigmata, on each side of the body. There is a longitudinal bar borne on the end of a papilla between each pair of stigmata. The stigmata do not project beyond the papillae. There is no continuity between consecutive stigmata of the first and second rows, as has been described by previous authors.

Dorsal lamina.—A smooth membrane.

Dorsal tubercle.—A plain oval.

Tentacles.—Well-spaced; 15 large alternating with 15 small.

Alimentary canal.—A simple loop transversely crossing the posterior third of the body. Oesophagus fairly long; stomach rectangular; intestine narrow with a cylindrical swelling on the ascending limb and a funnel-like thickening at the beginning of the transverse limb. The anus lies at the end of a slightly anteriorly directed rectum, which does not extend anteriorly to the base of the atrial aperture.

Gonads.—A small, compact ovary is placed in the alimentary loop. The testes are not seen, but may be dispersed.

Distribution.—Bermuda, east and west coasts of Florida (Van Name), Japan; Port Hacking, N.S.W.

Genus ECTEINASCIDIA Herdman

Key to Species of the Genus Ecteinascidia

1. Zooids under 3 mm. in length .. .. **E. euphues* Sluit.†
   **E. psammodes* Sluit. (Sluit. 1895)
   Zooids over 3 mm. in length 2
2. Tests confluent 3
   Zooids joined only by stolons 5
3. Longitudinal bar above every 3 stigmata 4
   Longitudinal bar above each stigmata .. .. *E. multiclathrata* Sluit. (Sluit. 1904)
4. Without languets on dorsal lamina .. .. *E. diligens* Sluit. (Sluit. 1900)
   With languets on dorsal lamina .. .. *E. nexa* Sluit. (Sluit. 1904)
5. Zooids bud off monaxial stolon .. .. *E. flora*, sp. nov.*
   Zooids bud off ramifying stolon 6
6. Well-marked siphons externally .. .. *E. sluiteri* Herd. (Herd. 1906)
   Sessile siphons externally 7
7. Ten bands of longitudinal muscles in mantle .. .. *E. solida* Herd. (Herd. 1906)
   Mostly transverse musculature in mantle 8
8. About 30-40 tentacles .. .. *E. diaphanis* Sluit. (Sluit. 1904)
   About 80 tentacles 9
9. Zooid clustered into dense hemisphere. Vas deferens ends ventral to rectum .. .. *E. moorei* Herd. (Herd. 1890)
   Zooid clustered into irregular mass. Vas deferens ends dorsal to rectum .. 10
10. Transversely elliptical dorsal tubercle .. .. .. *E. thurstoni* Herd. (Herd. 1906)
    Elongate, oval dorsal tubercle .. .. *E. turbinata* Herd. (Van Name 1945)

(1) Ecteinascidia flora, sp. nov.

Figs. 179, 180

External characters.—Zooids small, 3-4 mm. in length, arranged along a thin central stalk, with branches either side along its length becoming more plentiful and thinner terminally; similarly the zooids are largest basally, becoming successively smaller terminally. It appears that new zooids bud from the terminal part of the stalk as found in some monaxial plants. Both apertures sessile, the branchial terminal, the atrial one-third of body length distant.

Test.—Delicate, transparent.

Mantle.—Not very muscular; 6 lobes about the atriophore, 14 around the branchial opening.

Branchial tentacles.—Simple, long, numerous, and protruding through the branchial opening.

Dorsal lamina.—With well-marked, well-spaced languets at the ends of the transverse vessels.

Branchial sac.—Eighteen rows of oval, long stigmata; about 38 stigmata to a row; large, rounded papillae on the transverse vessels supporting thin, longitudinal vessels; about 2 stigmata per mesh.

† The reference is not available in Australia.

Alimentary canal (Fig. 179).—Forming a narrow loop in the posterior half of the left side of the body; oesophagus short; stomach almost spherical, smooth; duodenum short and sharply cut off from the wider intestine.

Gonads.—None apparent.

Relations.—The arrangement of zooids in the colony especially distinguishes this species from all others of which descriptions are available; zooids in colonies of the latter are joined by ramifying stolons. Descriptions of Sluiter's Australian species *E. euphues* and *E. psammodes* are not, however, available in Australia and must be compared at a later date.

Distribution.—Recorded from Lat. 28° 3.5′ S., Long. 113° E.

Family **CORELLIDAE**

Genus RHODOSOMA Ehrenberg

(1) Rhodosoma turcicum Savigny

Figs. 180, 181

For other references see Hartmeyer 1901.

1816 *Phallusia turcica* Savigny, pp. 102, 105; pl. 10, fig. 1 (see Hartmeyer 1909, p. 1389).
1828 *Rhodosoma verecundum* Ehrenberg, p. 3.
1855 *Schizascus pellucidas* + *S. papillosus* Stimpson, p. 377.
1865 *Chevreulius callensis* Lacaze-Duthiers, p. 293; pl. 5.
1878 *Rhodosoma seminudum* Heller, p. 91; pl. 1, fig. 5.
1882 *Rhodosoma pyxis* Traustedt, pp. 274, 285; pl. 4, fig. 4; pl. 5, figs. 15*a*, 15*b*.
1898 *Rhodosoma seminudum* Sluiter, p. 10.
1901 *Rhodosoma seminudum* Hartmeyer, p. 162; pl. 4, figs. 1-7.
1918 *Rhodosoma papillosum* Van Name, p. 113, figs. 68-71.
1918 *Rhodosoma pellucidum* Van Name, p. 113, figs. 68-71.
1921 *Rhodosoma pellucidum* Van Name, p. 392, figs. 69, 70.
1924 *Rhodosoma pellucidum* Van Name, p. 29.
1930 *Rhodosoma turcicum* Van Name, p. 471, fig. 43.
1932*b* *Rhodosoma papillosum* Oka, pp. 194-6.
1945 *Rhodosoma turcicum* Van Name, p. 203, figs. 116, 117.

External characters.—Fixed to a weed obliquely across the right side; the hinged lid or cover opens to the left. Around the lips of the lid are the conical and pointed papillae. Six definite and well-marked lobes protect the branchial opening and there are about 8 around the atrial opening, but they are not very well marked. The test around the latter opening is, however, more flaccid and the lobes are less well marked. The size of the smaller specimen from Port Noarlunga, S.A., is about 2.5 to 1.5 cm.

Test.—Transparent, glassy, thin but stiff, and smooth in the more posterior region. The test of the specimen from South Australia is less regular and smooth, with the pointed projections around the apertures obscured and smaller.

Mantle.—Thin.

Branchial sac.—With well-marked transverse vessels and more delicate longitudinal vessels borne on papillae arising from the transverse vessels. Stigmata 4 in number. There are no intermediate papillae.

Dorsal lamina.—Composed of a series of more or less triangular tentacular languets of average length.

Dorsal tubercle (Fig. 180).—Differing from those previously described in that it is not a simple horseshoe shape but consists of a transversely elongate slit with the right horn turned in. Anterior to the dorsal tubercle in the limb of the peritubercular area is a series of concentric folds around the oral aperture, accommodating tendons of muscles attached to the part of test concerned in the lid. Also leaving the mantle at right angles to these is another mass of these tendons. The folds appear to have some connection with the dorsal tubercle.

Alimentary canal.—The pyloric end of the stomach is a club-shaped caecum joined by a thin duct, and lying between the stomach and the intestine. No mention has been made in previous descriptions of this caecum, but it has probably been overlooked, since when it is empty of contents it is quite transparent (Fig. 181).

All other parts are as described by Van Name and others.

Distribution.—Wide: Mediterranean, Red Sea, Malaya, China, West Indies, California, Florida; Australia—Queensland and Port Noarlunga, S.A.

Genus CORELLA Alder and Hancock

Key to Species of the Genus Corella

1. With sessile apertures .. .. *C. japonica* Traust. 1882 (Oka 1935)
   Without sessile apertures 2
2. Less than 30 tentacles .. .. *C. minuta* Traust. (Van Name 1945)
   More than 50 tentacles 3
3. Twenty to 24 internal longitudinal bars on each side . *C. willmeriana* (Herd. 1898)
   More than 50 horizontal longitudinal bars . *C. eumyota* Traust.* (Van Name 1945)

(1) Corella eumyota Traustedt

1882 *Corella eumyota* Traust. (but not specimen from Bahia), pp. 271, 273, pl. 4, figs. 2, 3; pl. 5, figs. 13, 14.
1884 *Corella novarae* von Drasche, p. 382, pl. 8, figs. 1-4.
1885 *Corella eumyota* Traustedt, p. 9.
1897 *Corella eumyota* Sluiter, p. 40, pl. 5, fig. 14.
1900 *Corella eumyota* Michaelsen, p. 10.
1905*b* *Corella antarctica* Sluiter, p. 471.
1906 *Corella antarctica* Sluiter, p. 31, fig. 1, pl. 2, figs. 29-32, pl. 5, fig. 56.
1907 *Corella eumyota* Michaelsen, p. 74.
1910 *Corella eumyota*, Herdman, p. 6, pl. 3, figs. 1-6.
1911 *Corella eumyota* Hartmeyer, p. 458, pl. 45, fig. 8, pl. 51, figs. 6-9.
1913 *?Corella benedeni* Van Beneden and Selys-Longchamps, p. 9, pl. 1.
1913 *Corella dohrni* Van Beneden and Selys-Longchamps, p. 15, figs. *a*, *b*, pl. 2.
1914 *Corella eumyota* Sluiter, p. 26.

1920 *Corella eumyota* Hartmeyer, p. 132.
1921 *Corella eumyota* Van Name, pp. 397, 483.
1923 *Corella eumyota* Herdman, pt. 3, p. 30; pl. 13, figs. 7, 8.
1923 *Corella dohrni* Herdman, pt. 3, p. 30.
1929 *Corella eumyota* Arnbäck, p. 7; pl. 1, figs. 10-14.
1938 *Corella eumyota* Arnbäck, p. 40.
1938 *Corella dohrni* Arnbäck, p. 41.
1938 *?Corella benedeni* Arnbäck, p. 41.
1945 *Corella eumyota* Van Name, p. 212.

Description.—Numerous specimens were available and varied in size from 2 to 5 cm. in length and in breadth from 1 to 3 cm. The branchial siphon is terminal and cylindrical. The small and wart-like atrial siphon is half-way down the dorsal surface.

Nothing further can usefully be added to descriptions already given.

Distribution.—"S. American coasts from Valparaiso and the Juan Fernandez Is. south through the Magellanic region, the Falkland Is., and north on the east coast at least to Puerto Madryn, Argentina. It extends south into the Antarctic (Graham Land region, Kaiser Wilhelm II Land). It is recorded also from the Cape of Good Hope, St. Paul Is., Indian Ocean; New Zealand (Cook Strait) and the Auckland Islands and Tasmania" (Van Name 1945). Also Balnarring Beach, Vic.; D'Entrecasteaux Channel, Tas.; Trigg's I., W.A.

Family **CIONIDAE**

Genus CIONA Fleming

(1) Ciona intestinalis Linnaeus

1765 *Tethyum sociabile* Gunnerus, p. 99, pl. 3, pp. 3-4.
1767 *Ciona intestinalis* Linnaeus, p. 1087.
1777 *Ascidia canina* O. F. Mueller, p. 225.
1822 *Ciona intestinalis* Fleming, p. 512.
1838 *Ascidia intestinalis* Couthouy, p. 111.
1843 *Ascidia intestinalis* Dekay (Ascidia), p. 259.
1850 *Ascidia ocellata* Agassiz, p. 159.
1851 *Ascidia intestinalis* Sars, p. 156.
1852 *Ascidia tenella* Stimpson, p. 228.
1854 *Ascidia tenella* Stimpson, p. 20.
1859 *Ascidia intestinalis* Sars, p. 64.
1860 *Ascidia tenella* Stimpson, p. 2.
1870 *Ascidia tenella* Binney, p. 24.
1870 *Ascidia tenella* Dall, p. 255.
1870 *Ascidia ocellata* Binney, p. 24, pl. 24, fig. 332.
1870 *Ascidia ocellata* Dall, p. 255.
1871 *Ciona tenella* Verrill, p. 99, figs. 12, 13.
1872*a* *Ciona tenella* Verrill, p. 6.
1872*b* *Ciona tenella* Verrill, p. 214.
1873-4 *Ciona tenella* Verrill, vol. 6, pp. 435, 440, vol. 7, pp. 413, 504.
1873 *Ciona tenella* Verrill and Smith, p. 698.
1878 *Ciona intestinalis* Heller, p. 83.
1879 *Ciona intestinalis* Schmeltz, 7: 89.

1880 *Ciona tenella* Verrill, p. 251.
1880 *Ciona canina* Traustedt, p. 432.
1880 *Ciona ocellata* Verrill, p. 251.
1889 *Ciona ocellata* McDonald, p. 858.
1896 *Ciona intestinalis* Castle, pl. 1-13.
1899 *Ciona intestinalis* (?) Herdman, p. 9.
1901 *Ciona tenella* Kingsley, p. 183.
1901 *Ciona tenella* Whiteaves, p. 267.
1903 *Ciona intestinalis* Hartmeyer, p. 297, pl. 12, fig. 13.
1903 *Ciona ocellata* Hartmeyer, p. 301.
1903 *Ciona tenella* Hartmeyer, p. 301.
1909 *Ciona intestinalis* var. *sydneiensis* (non Stimpson 1885) and *Ciona diaphanea* Kesteven, p. 282, pl. 27, figs. 13-19, p. 285.
1912 *Ciona intestinalis* var. *tenella* Van Name, p. 608.
1912 *Ciona intestinalis* Van Name, p. 606, fig. 43, pl. 66, fig. 130.
1912*a* *Ciona intestinalis* Huntsman, p. 112.
1912*a* *Ciona intestinalis* Huntsman, pp. 114, 119.
1912*b* *Ciona intestinalis* Huntsman, p. 108, pl. 14, fig. 4.
1913 *Ciona intestinalis* Ritter, p. 500.
1913 *Ciona intestinalis* Osburn, Sumner, and Cole, p. 730.
1915*a* *Ciona sociabilis* Hartmeyer, p. 321.
1915*b* *Ciona sociabilis* Hartmeyer, p. 254.
1916 *Ciona intestinalis* Pratt, p. 667, fig. 1012.
1917 *Ciona intestinalis* Ritter and Forsyth, p. 457.
1920 *Ciona intestinalis* Hartmeyer, p. 210.
1924 *Ciona intestinalis* Hartmeyer, p. 90.
1924 *Ciona intestinalis* var. *ocellata* Hartmeyer, p. 104.
1924 *Ciona intestinalis* var. *tenella* Hartmeyer, p. 103.
1928 *Ciona intestinalis* Hartmeyer and Michaelsen, p. 259.
1934 *Ciona intestinalis* var. *tenella* Arnbäck, ser. 3, vol. 13, pt. 4, No. 3, p. 17.
1945 *Ciona intestinalis* Van Name, p. 160.

External characters.—The typical form is 5-15 cm. long and 1-4 cm. in breadth. The body is more or less cylindrical. The broad, wide, cylindrical branchial siphon is placed anteriorly and the narrower atrial siphon antero-dorsally. Posteriorly the test may or may not be thickened, and occasionally it may taper to a point and bear small, short, root-like processes. Occasionally tubiculous worms and investments of compound ascidians are found attached to the test.

Mantle.—With typical longitudinal muscle bands.

Dorsal tubercle.—A simple, U-shaped slit turned anteriorly and to the right.

Branchial sac, alimentary canal, and *gonads.*—These, in Australian specimens, all conform exactly to the descriptions given by previous authors.

Distribution.—(Van Name 1945) "Mediterranean; Black Sea; waters of Northern Europe and parts of the Arctic region from Greenland and Davis Strait south to southern Massachusetts and Rhode Is. and on the Pacific coast from southern Alaska to the southern end of California. Harbours of Suez, Singapore (Hartmeyer 1903), Straits of Magellan,

Japan (probable transport by ship)". Also Rockhampton, Fremantle, Albany, Port Adelaide, Hobart, Port Jackson. This species is found to thrive especially in estuarine conditions (e.g. at Port Adelaide and in Swan River, W.A.).

III. Distribution of Ascidians in the Australian Area

In the foregoing text, isolated records of species, previously recorded from other parts of the world, lead to consideration of their possible introduction into this area:

(*a*) *Polycarpa thelypanes* Sluiter.—On the oyster shells of the Pacific oyster introduced to Oyster Harbour, Albany, W.A. Sluiter has previously recorded this species from the Sulu Archipelago in the Philippines, hence it may have been introduced with the oysters. It is found here, however, in conjunction with *Pyura jacatrensis* Sluiter, which, in addition to Sluiter's record from the Philippines has also been found in Malaya, the Celebes, Batavia, Cape Jaubert in Western Australia, and also on the west coast at Shark Bay, Trigg's I., Cottesloe, and Fremantle. So it is possible that *P. thelypanes* has a similar distribution, extending from Japan to as far as Albany on the south-west coast of Australia.

(*b*) *Halocynthia hispida* Herdman.—*H. hispida* var. *crinitistellata* Herdman, recorded from Ceylon and Port Jackson; *H. hispida* var. *typica* Herdman from Bass Strait and D'Entrecasteaux Channel in Tasmania. Therefore, since there is a closely related form in its southern range, it seems unlikely that this form has been introduced, and its range may also extend down the west coast. At Port Jackson and D'Entrecasteaux Channel both varieties are, however, very numerous.

(*c*) *Ascidia aspersa* Müller.—Found from the Shetland Islands to the Mediterranean; at Oyster Harbour, Albany, W.A.; Port Noarlunga, S.A.; Otago Harbour, New Zealand. Brewin (1946) has suggested that the appearance of the species in New Zealand may be due to the introduction by shipping, but its appearance at points on the south coast of Australia suggests a cosmopolitan distribution.

(*d*) *Ascidia nigra* (Savigny).—Recorded from the Red Sea, the east coast of North and South America, the Gulf of Aden, and from Pittwater in New South Wales.

(*e*) *Ascidia austera* Sluiter.—Recorded from Malaya, from Moreton Bay and Thursday Island in Queensland, and from Albany in Western Australia.

(*f*) *Pyura subuculata* Sluiter.—Found plentifully in association with *Microcosmus claudicans* at Port Noarlunga in South Australia, and in the Outer Harbour, Adelaide. Brewin has recorded the species from Hauraki Gulf in New Zealand, where it is found in association with *Microcosmus kura* Brewin. The writer has found no distinction between the latter

species and *Microcosmus claudicans*, and it is interesting that in the only records of the *Pyura* species in Australasia it occurs in the same association, though the two areas are widely separated, and not regarded as the same zoogeographical region, nor even as a similar ecological community.

The following species are recorded from all around the Australian coast:

(*a*) *Styela stolonifera* Herdman.
(*b*) *Polycarpa pedunculata* Heller.
(*c*) *Herdmania momus* Sav. var. *grandis* (Heller): from Albany to Geraldton along the west coast; from Bowen in Queensland to Port Phillip in Victoria on the east.
(*d*) *Microcosmus claudicans* Savigny.
(*e*) *Molgula sabulosa* Quoy and Gaimard.
(*f*) *Styela plicata* Lesueur.

The following species are recorded from the west coast:

(*a*) *Styela irma* Hartmeyer: Shark Bay to Albany.
(*b*) *Polyandrocarpa australiensis*, sp. nov.: Trigg's I. to Hamelin Bay.
(*c*) *Oculinaria australis* Gray: Fremantle to Albany.
(*d*) *Amphicarpa diptychos* Hartmeyer: Cape Jaubert in Western Australia to D'Entrecasteaux Channel in Tasmania.
(*e*) *Pyura pachydermatina* Herdman var. *gibbosa* Herdman from Fremantle to Walkerville in Victoria.
(*f*) *Pyura jacatrensis* Sluiter: Cape Jaubert to Albany.
(*g*) *Pyura leeuwinia*, sp. nov.: Trigg's I. to Albany.
(*h*) *Molgula nodosa* Hartmeyer: Fremantle to Bunbury.
(*i*) *Ascidia gemmata* Sluiter: Cape Jaubert, Albany, W.A.; San Remo, Vic.; Port Jackson, N.S.W.

The following species are recorded from the south coast:

(*a*) *Styela etheridgii* Herdman: both "*personata*" and "*etheridgii*" forms are found from Trigg's I. in the west to Port Curtis in Queensland, and in South Australia and Victoria.
(*b*) *Polycarpa moebii* Michaelsen: Trigg's I., W.A., to Bowen, Queensland.
(*c*) *Stolonica australis* Michaelsen: Albany to Spring Bay in Tasmania.
(*d*) *Molgula janis*, sp. nov.: at Walkerville, Vic., and Victor Harbour, S.A.
(*e*) *Ascidia obesa* (Herdman): Shark Bay to Port Jackson.
(*f*) *Symplegma viride* Herdman: extending from Malaya to the west coast of Australia; also south to Albany and across to South Australia.
(*g*) *Pyura australis* (Quoy and Gaimard) var. *typica* Quoy and Gaimard: Geraldton to D'Entrecasteaux Channel.

The following species are recorded from the east coast:

(*a*) *Polycarpa attollens* Herdman: The Solomons, Port Curtis and the Barrier Reef in Queensland, and Port Jackson, N.S.W.

(*b*) *Polycarpa rigida* Herdman: from Bass Strait to Port Stephens in New South Wales.

(*c*) *Polycarpa obtecta* Traustedt: D'Entrecasteaux Channel, Tasmania, to Port Jackson; also found in the West Indies and on the east coast of North and South America.

(*d*) *Pyura pachydermatina* (Herdman) var. *intermedia* Herdman: Bass Strait to Coff's Harbour in New South Wales. It takes the place of the closely related var. *gibbosa* which occurs on the west coast from Fremantle and as far east as Walkerville in Victoria

(*e*) *Pyura spinifera* (Quoy and Gaimard): Bass Strait to Port Jackson.

(*f*) *Pyura irregularis* (Herdman): Outer Harbour (Adelaide), D'Entrecasteaux Channel, Port Jackson.

(*g*) *Pyura stolonifera* Heller f. *praeputialis* Herdman: Outer Harbour, South Australia, and continuously south to Spring Bay in Tasmania and north to Moreton Bay in Queensland.

(*h*) *Microcosmus spinifera* Herd.: Port Jackson to Moreton Bay.

(*i*) *Molgula mollis* Herd.: Port Jackson to Twofold Bay in New South Wales.

The following species extend to the north coast:

(*a*) *Styela plicata* Les.: Garden I. (Fremantle) in the west and thence north to Botany Bay in the east.

(*b*) *Polycarpa aurita* Sluiter: Malaya, Cape Jaubert and the Great Barrier Reef.

(*c*) *Polycarpa aurata* Q. & G.: Malaya, Shark Bay, Cape Jaubert, and Port Jackson.

(*d*) *Microcosmus helleri* Herd.: Cape Jaubert, Shark Bay, Torres Strait, Great Barrier Reef.

Discussion (*Figs.* 182, 183)

From the data set out above, certain generalizations may be made concerning geographical boundaries as evidenced by the simple ascidian population. Species typical of the Indo-Malayan region extend in range down the west coast of Australia. These species, with others, occupy the *Damperian* region of Hedley (this region extends to between Shark Bay and Fremantle). From Fremantle to Albany there is a very distinctive fauna, which is quite distinct from the southern fauna of the *Flindersian* region in which this area has previously been grouped. It corresponds to Iredale's *Autochthonian Faunula* in the *Leeuwinian* area, and an appro-

priate name for the marine region would be *Baudinian* (if there were sufficient evidence from other phyla that the fauna is distinctive). Water temperatures in the area accord with isothermic limits of 65° and 70°F. (Hedley 1904).

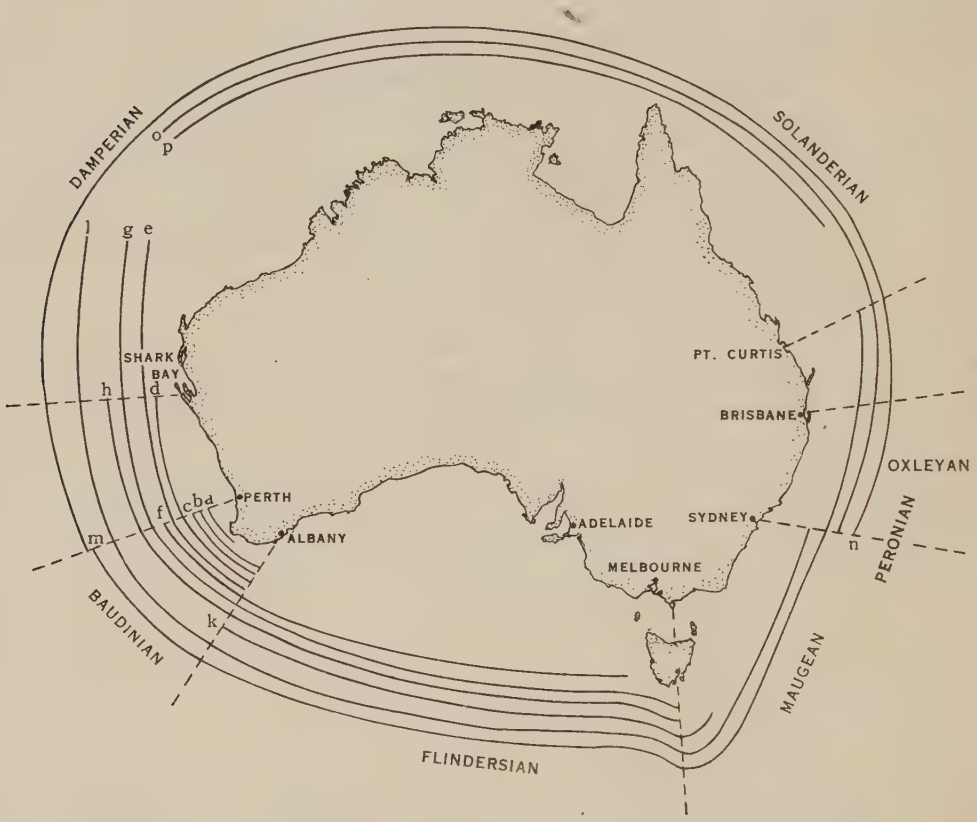


Fig. 182.—Range of distribution of western, northern, and southern species and marine regions. *a, Polyandrocarpa australiensis; b, Oculinaria australis; c, Pyura leeuwinia; d, Styela irma; e, Pyura jacatrensis; f, P. pachydermatina* var. *gibbosa; g, Amphicarpa diptychos; h, Pyura australis; k, Stolonica australis; l, Ascidia gemmata* and *A. obesa; m, Styela etheridgii; n, S. plicata; o, Polycarpa aurata; p, P. aurita* and *Microcosmus helleri;* and *q, Molgula janis.*

The species typifying the *Flindersian* Marine region (*Adelaidean* region of Hedley (1904)) extend from Albany to the west coast of Tasmania. There is a transition at D'Entrecasteaux Channel in Tasmania to the fauna of the *Maugean* sub-region of Iredale (see Whitley 1932), which as originally defined is limited to the south-east coast of Tasmania, but the ascidian fauna extends as far north as Port Jackson. From Port Jackson to Moreton Bay, in an area corresponding to Iredale's *Oxleyan* sub-area, is an ascidian fauna which may be distinctive owing to the sheltered conditions offered by the many natural harbours in the area; for the present it may

be termed the *Oxleyan* marine sub-region. These two sub-regions therefore, occupying the coast from D'Entrecasteaux Channel to Moreton Bay, comprise Iredale's *Peronian* region (Whitley 1932).

Fig. 183—Range of distribution of eastern Australian species. *a, Polycarpa attollens; b, Pyura pachydermatina* var. *intermedia; c, Polycarpa rigida; d, Pyura spinifera; e, Microcosmus spinifera; f, Polycarpa obtecta; g, Pyura irregularis; h. P. stolonifera;* and *k, Molgula mollis.*

The *Solanderian* fauna extends northwards along the Barrier Reef and the Queensland coast, and there is no distinction from the known ascidian distribution between *Banksian* and *Solanderian* faunas. The *Damperian* fauna extends across the north of Australia, through Torres Strait to the north-west coast (Shark Bay and Cape Jaubert).

There is an overlap of species between Shark Bay and Fremantle representing the transition from the *Damperian* to the *Baudinian* region, and between Moreton Bay and Port Curtis representing the transition between the *Solanderian* and *Peronian* regions.

No data are yet available on limits of depth. Most of the species mentioned here are recorded from shallow waters, usually just below low tide and from the intertidal region.

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